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The fossil on the cover is *Trilophodon sendaicus* Matsumoto, an extinct elephant, which was described from the Pliocene Tatsunokuchi Formation developed in the vicinity of Sendai, Northeast Honshu, Japan. (IGPS coll. cat no. 87759 (A), length about 18.5 cm)

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### **PALAEONTOLOGICAL SOCIETY OF JAPAN**

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## 917. FOSSIL BRYOZOANS FROM THE LOWER GONDWANA SISNE FORMATION, NEPAL LESSER HIMALAYAS\*

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**Abstract.** A newly proposed bryozoan species, *Pamirella nepalensis* Sakagami and Sakai, found from a limestone block which was derived from the upper part of the Sisne Formation, Nepal Lesser Himalayas, is described. It is highly possible that the species indicates a middle Early Permian (Artinskian) age and that it provides a datum for establishing the geological age of the formation.

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**Key words.** Bryozoa, Nepal Lesser Himalayas, *Pamirella*, Permian

### Introduction

Some bryozoan fossil remains have hitherto been known from the so-called "Fenestella Shale" in the Himalayan region, which is well known to represent part of the Lower Gondwana sequence of late Carboniferous or Carboniferous to Permian age for some students (Ganestan, 1972; Gansser, 1964; Krishnan, 1982; Jani and Das, 1973; Sakai, 1983). These previously reported bryozoans, however, include only fenestellids such as *Fenestella*, *Dogaddanella*, *Polypora*, *Protoretopora* and *Acanthocladia*, and are usually in a poor state of preservation.

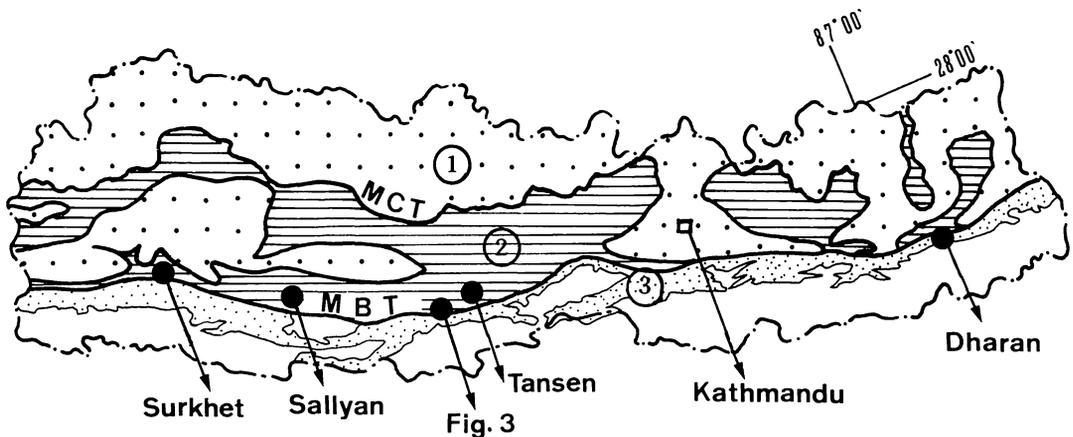
As already mentioned by Sakai (1983), some blocks (floats) of shale which abundantly contain fenestellid bryozoans were collected near the boundary fault between the Kali Gandaki Supergroup and the Tansen

Group in the upper reaches of the Badahare river of west Central Nepal. These blocks are considered to have been derived from the upper part of the Sisne Formation. Sakai (1983) reported some bryozoan remains of the genera *Fenestella*, *Polypora* and *Acanthocladia*, but their specific identification could not be made because of the poor state of preservation. They are reported to be possibly of Carboniferous to Permian age.

Additional bryozoan fossils were obtained from an impure limestone block which was derived from the upper part of the Sisne Formation. They are somewhat better preserved than the previous specimens. In this paper, we present a brief note on the geology of the fossil locality and describe paleontologically one new bryozoan species. This is the first report of fossil bryozoans from the Nepal Lesser Himalayas.

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**Figure 1.** Geotectonic division of the Nepal Himalayas and four main areas where the Lower Gondwana beds are distributed. 1. Central and Lesser Himalayan Crystallines, Tethys sediments and Tertiary granite; 2. Lesser Himalayan sediments; 3. Siwalik Group. MCT: Main Central Thrust, MBT: Main Boundary Thrust.

### Geological outline

The Lesser Himalayan sediments in west Central Nepal (Figure 1) are grouped into two major divisions; the Kali Gandaki Supergroup of late Precambrian to early Paleozoic age and the disconformably overlying Tansen Group. The Tansen Group comprises five formations; the Sisne, Taltung, Amile, Bhainskati and Dumri Formations in ascending order (Figure 2). The former three are the Gondwana rocks and the latter two are the post Gondwana rocks. The lower Gondwana Sisne Formation is distributed extensively in the outer belt of the Lesser Himalayas, and its eastern and western continuation is disconnectedly distributed in the frontal range near the Main Boundary Thrust in Dharan, Sallyan and Surkhhet (Figure 1).

The Sisne Formation in the Tansen area is mainly composed of a glacial diamictite, fluvial sandstone and bioturbated rhythmite beds of thin sandstone and shale in the uppermost part (Sakai, 1983). The fossil bryozoans were discovered from a large limestone block in the upper reaches of the Badahare Khola (S1 of Figure 3) and from cobble-sized

shale floats in the upper stream of the Amile Khola (S2 of Figure 3). The block and floats must have been derived from the Sisne Formation because their lithologies are identical to the bioturbated rhythmite and shale, respectively, of the formation.

### Fossil bryozoans and their age

Abundant bryozoan remains occur in association with some crinoid stems and a small amount of brachiopod fragments in an impure limestone block (ca. 90 cm in length) exhibiting a lithology of calcareous shale and limestone interbeds. Angular, detrital quartz grains are usually mixed with skeletal debris in the limestone. They are considered to have been swept up and deposited in muddy tidal flats during a storm (Sakai, 1983).

The following three bryozoan species could be discriminated: *Pamirella nepalensis*, n. sp., *Fenestella* sp. indet. and *Polyppora* sp. indet. Although the genus *Pamirella* established by Gorjunova (1975) is now known to range from the Lower Carboniferous to Lower Permian (Artinskian), *Pamirella nepalensis*, n. sp. is nearest to *P. pulchra* (Bass-

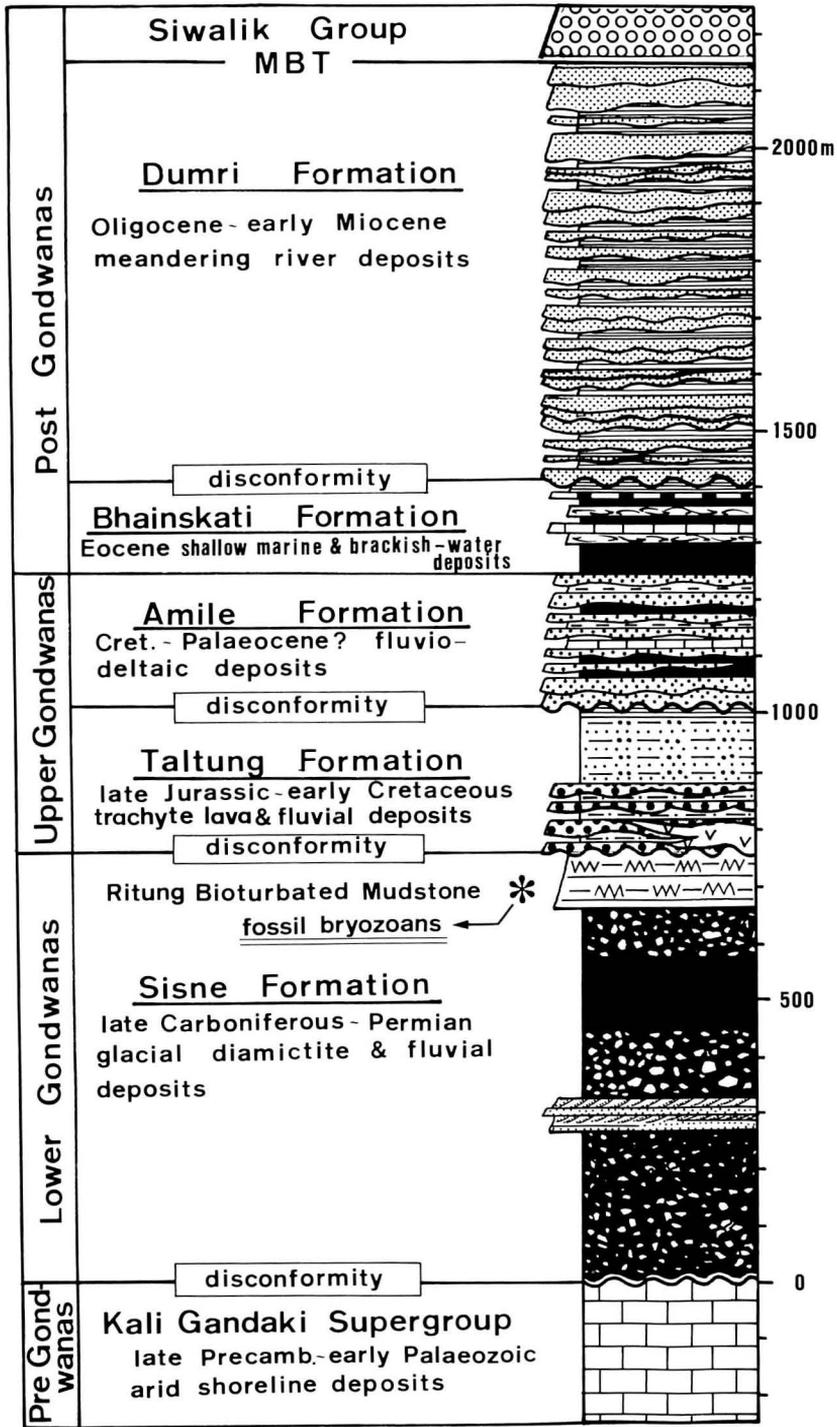
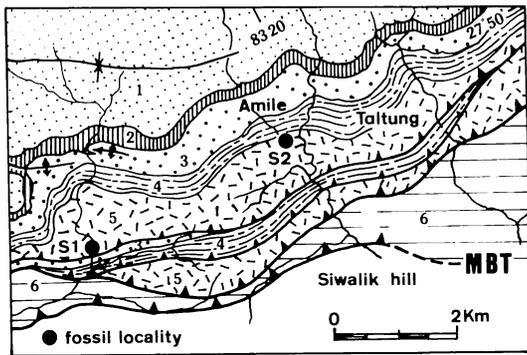


Figure 2. Stratigraphic section of the Tansen Group and the horizon of fossil bryozoans, after Sakai (1983).



**Figure 3.** Geological map around the fossil localities (S1, S2). 1. Dumri Formation; 2. Bhainskati Formation; 3. Amile Formation; 4. Taltung Formation; 5. Sisne Formation; 6. Kali Gandaki Supergroup.

ler) which was originally described from the Lower Permian of Bitauini in Timor Island of Indonesia. The genera *Fenestella* and *Polypora* are both known to range from the Ordovician to Permian, especially being very common in the Carboniferous and Permian. *Fenestella* sp. and *Polypora* sp. are both indeterminate because of their possession of rare and fragmentary zoaria. Thus, the present bryozoan faunule is highly possible to indicate a middle Early Permian (Artinskian) age.

In the Kumaun and Garhwal Lesser Himalayas in India, the Blaini Formation with glacial diamictite beds has long been believed to represent a northern continuation of the Lower Gondwana sequence in the peninsular India. However, recent findings of Cambrian trilobites and archaeocyatha from the Tal and Krol Formations, which overlie the Blaini Formation, disclosed that the Blaini diamictite is not late Paleozoic but late Precambrian in age (e.g., Singh and Rai, 1983; Joshi *et al.*, 1989). Under these circumstances, the present finding of bryozoan fossils of Permian age from the Sisne Formation evidently testifies that the Lower Gondwana sequence exists in the central sector of the Himalayas.

### Description of a new species

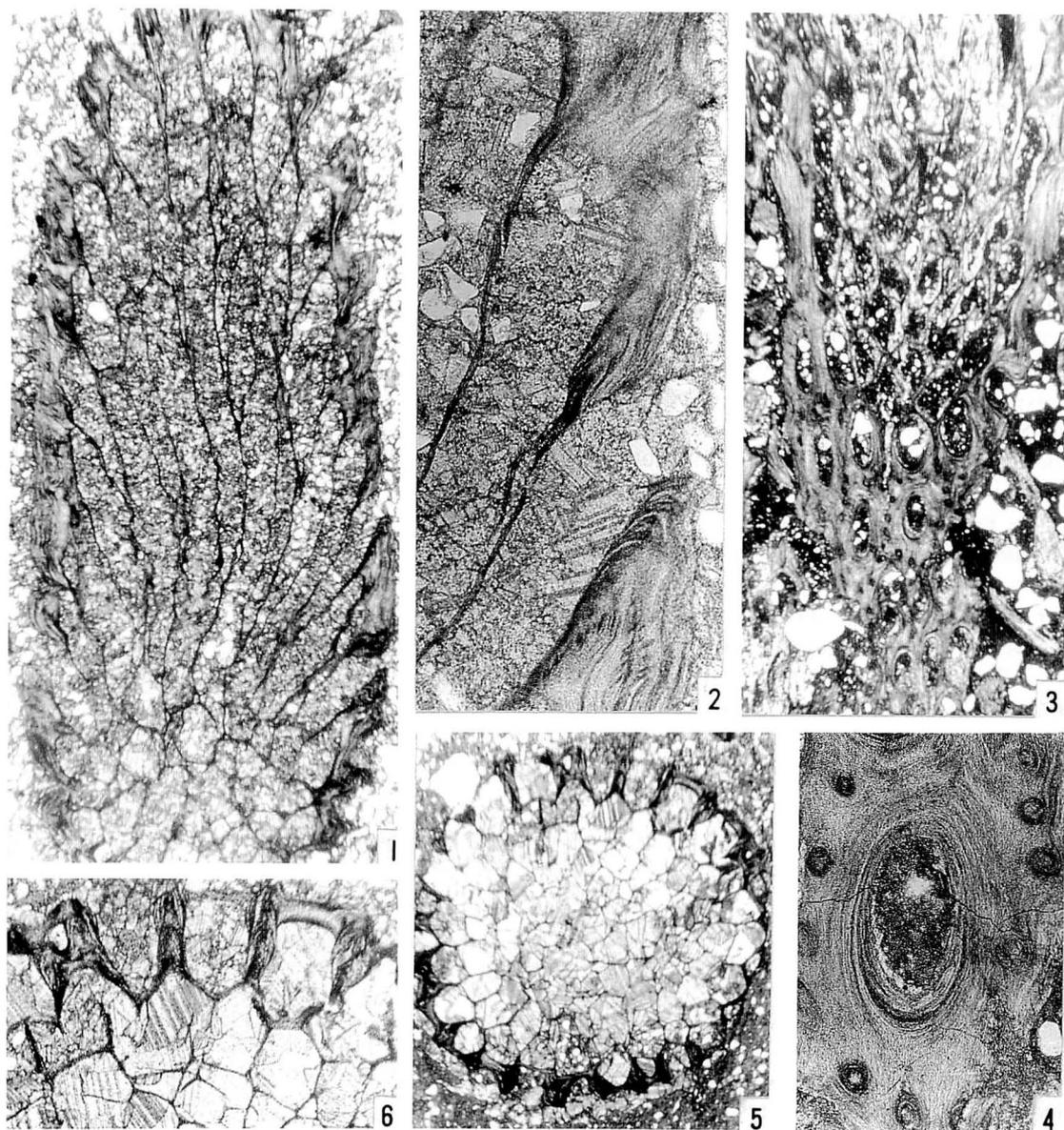
Genus *Pamirella* Gorjunova, 1975  
*Pamirella nepalensis* Sakagami  
 and Sakai, n. sp.

Figures 4-1-6

*Description.*— Zoarium cylindrical, nearly straight stem, branching mode not observed, 1.2 to 2.5 mm in diameter. Surface specimen could not be examined but observation of tangential section near surface suggests that zooecial apertures being not regularly arranged in any directions. Exozone very thin for the diameter, about 0.2 to 0.3 mm in thickness. Ratio of half a diameter of zoarium to exozone 3:1 to 4:1.

Zooecial tube straight and very long, parallel to longitudinal direction in the endozone, and rapidly curved outwards at the inner edge of exozone. Zooecial tubes very short in exozone, 0.2 to 0.3 mm in length and oriented at an angle of about 60 to 90 degrees to stem surface. Zooecial wall very thin and nearly straight in endozone, abruptly thickened in exozone. Superior and inferior hemisepta lacking. Zooecial wall laminae rather coarse and generally parallel to the surface except for the acanthostyle (megacanthopore) position where the laminae are swelled out. Diaphragm and metapore lacking. In tangential section of exozone, zooecial tube being elongated oval, longer diameter ranging from 0.128 to 0.192 mm. Twelve to fifteen well-developed acanthostyles consisting of a rather clear central tube with dark-colored concentric fibrous tissue, and surrounding zooecial tube in one row in interspaces of zooecia. Outer diameter of acanthostyle ranging from 0.038 to 0.058 mm. In transverse section, zooecial tube in endozone irregularly polygonal.

*Remarks.*—Blake (in Boardman *et al.*, 1983) included the following six species in the genus *Pamirella*: *Pamirella nitida* Gorjunova (the type species), *Rhombopora pulchra* Bassler, *R. orientalis* Bassler, *R. nicklesi*



**Figure 4.** *Pamirella nepalensis* Sakagami and Sakai, n. sp. **1**, longitudinal section, Reg. no. GKD-30705,  $\times 20$ . **2**, enlarged part of 1,  $\times 80$ . **3**, tangential section, Reg. no. GKD-30706,  $\times 20$ . **4**, enlarged part of 3,  $\times 80$ . **5**, transverse section, Reg. no. GKD-30707,  $\times 20$ . **6**, enlarged part of 5,  $\times 40$ .

Ulrich, *R. minor* Ulrich and *R. ? asperula* Ulrich. Among them, the latter three species were originally described from the Lower Carboniferous of North America, but they seem to be quite different from the present new species. The present form is in general

appearance not unlike the type species, *P. nitida* which was described from the upper part of the Bauzardarinsk Formation (Artinskian of the Lower Permian) in the southeastern part of Pamir, but it is distinguished from the type species in the mode of zooecial tubes

and by the smaller diameter of acanthostyle. The present form seems to be nearest to *P. pulchra* which was described from the Lower Permian of Bitauini in Timor Island of Indonesia by Bassler (1929). The present form, however, can be distinguished easily from *P. pulchra* in having the very long, parallel zooecial tubes in endozone and the extremely thin exozone.

*Occurrence and Geological age.*—Specimens of this new species were found in a dark gray, impure limestone block which was derived from a horizon in the upper part of the Sisne Formation of the Tansen Group. The geological age is uncertain, but it is estimated to be assignable to the Artinskian (Early Permian).

*Repository.*—The specimens treated in this paper are deposited in the collections of Department of Earth and Planetary Sciences, Faculty of Science, Kyushu University. Reg. nos. GKD-30705 (holotype), GKD-30706 and GKD-30707 (paratypes). The other thin sections, Reg. nos. GKD-30708, GKD-30709, GKD-30710 and GKD-30711, are prepared.

#### Acknowledgements

The geological survey was done by one of us (H. Sakai) as part of his activities in the Japan Overseas Cooperation Volunteers (JOCV) service. During the course of investigation, Dr. M.P. Sharma, Mr. B.M. Pradhan and all other staff members of Department of Geology, Tribhuvan University, gave Sakai every facility and valuable advice. JOCV financially supported the field works. We

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ネパール、レッサーヒマヤラに分布する、Sisne Formation から流出した石灰岩の転石から、コケムシ化石の新種 *Pamirella nepalensis* Sakagami and Sakai を識別し記載した。恐らくこの種は前期二疊記中期 (アルティンスク世) を指示すると考えられ、Sisne Formation の地質時代を考察するための1つのデータを提供するものである。また、Sisne Formation は、その岩相と合せ考え、インド半島の下部ゴンドワナ系の北方延長とみなすことができる。

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坂上澄夫・酒井治孝

## 918. PALEOENVIRONMENTAL TRANSITION AT 1.2 MA IN THE OMMMA FORMATION, CENTRAL HONSHU, JAPAN\*

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**Abstract.** A marked change of paleoenvironment took place at the transition from the lower to the middle part of the Omma Formation, at about 1.2 Ma. Cyclicity in litho- and biofacies is distinctly wrought in the middle part. Each cycle in the middle part consists of a fining-upward sequence which starts with a shell bed and ends with a muddy sandstone. Within each cycle, molluscan associations change from those indicative of cold and shallow waters to warm and deeper waters. This observed cyclicity has an amplitude up to 50 m in water depth and an estimated periodicity of 28,000 years on the average and is attributed to glacio-eustatic sea-level fluctuations.

Even the molluscan composition suggests that water depth was shallower than 20-30 m during the deposition of nearly all of the lower part, whereas cyclic changes of litho- and biofacies as seen in the middle part are not developed in the lower part. This contrast can be interpreted due to the increase of amplitude of glacio-eustatic sea-level changes at about 1.2 Ma. At least nine periods of influx of warm-water are detected in the middle part for a time span of 0.3 million years between 1.2 and 0.9 Ma, whereas only one is detected from the lower part spanning a time interval of about 0.16 million years. This apparent change in the frequency of warm-water influxes may also be ascribed to the increase of amplitude of glacio-eustatic sea-level changes.

This 1.2 Ma date of the marked transition of paleoenvironment in the Omma Formation seems to be synchronous with the initiation time of intensified glaciation in Europe and North America as recorded in oxygen isotope signatures and glacial debris in deep-sea sediments.

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**Key words.** Glacio-eustasy, intensification of glaciation, 1.2 Ma, Omma Formation, Omma-Manganji Fauna.

### Introduction

The Omma-Manganji Fauna is widely distributed in marine Pliocene and Pleistocene formations along the Japan Sea coast, from Cheju (or Saishu) Island, Korea, through Ishikawa, Toyama, Niigata, Yamagata, Akita and Aomori Prefectures to southern Hokkaido. This fauna named by Otuka (1936, 1939a, b) has been recognized as the cold-water molluscan fauna characteristic of the Japan Sea.

The type section of the Omma Formation in Ishikawa Prefecture, the section studied here, is known as one of representative localities of the Omma-Manganji Fauna. Many works have dealt with the molluscan fauna of the Omma Formation (*e.g.* Kaseno and Matsuura, 1965; Ogasawara, 1977, 1981; Matsuura, 1985). Ogasawara (1981, 1983, 1986) divided the molluscan fauna of this formation into two faunas, "the Omma proper" and "the Younger Ommaian". The Younger Ommaian Fauna is found in the upper part of the section and is characterized by the dominance of extant and warm-water species. Accord-

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ing to Ogasawara (1981), the Omma proper Fauna occurs in the rest of the Omma Formation and is characterized by the common occurrence of extinct species and those species which lived in shallow waters, from littoral to 50–60 m depths.

Recently, Kitamura and Kondo (1990) analyzed temporal changes in lithofacies and molluscan fossil associations, based on detailed field observations at the type section of the Omma Formation. They divided the formation into three parts, lower, middle and upper. The "Omma proper Fauna" occurs from the lower and middle parts. The middle part of the formation exhibits at least ten successive sedimentary cycles. Each cycle shows a time-progressive change in molluscan associations from the cold-water, upper sublittoral associations in the lower portion of the cycle, to the warm-water, lower sublittoral associations in the upper portion. They concluded that this change from cold and shallow water to warm and deep water environments was due to glacio-eustatic changes.

Certain records of glacio-eustatic sea-level fluctuation can also be expected in the lower part of the Omma Formation, as compared with the oxygen isotope record of deep-sea stratigraphy (e.g., Williams *et al.*, 1988). No such signals have, however, been recognized in either molluscan associations or lithofacies. This fact suggests that a paleoenvironmental transition is likely to have taken place sometime at the boundary between the lower and middle parts of the Omma Formation. This paper intends to summarize the stratigraphic context of the Omma-Manganji Fauna in the lower and middle parts of the Omma Formation at the type section, and to document the transition.

#### Acknowledgments

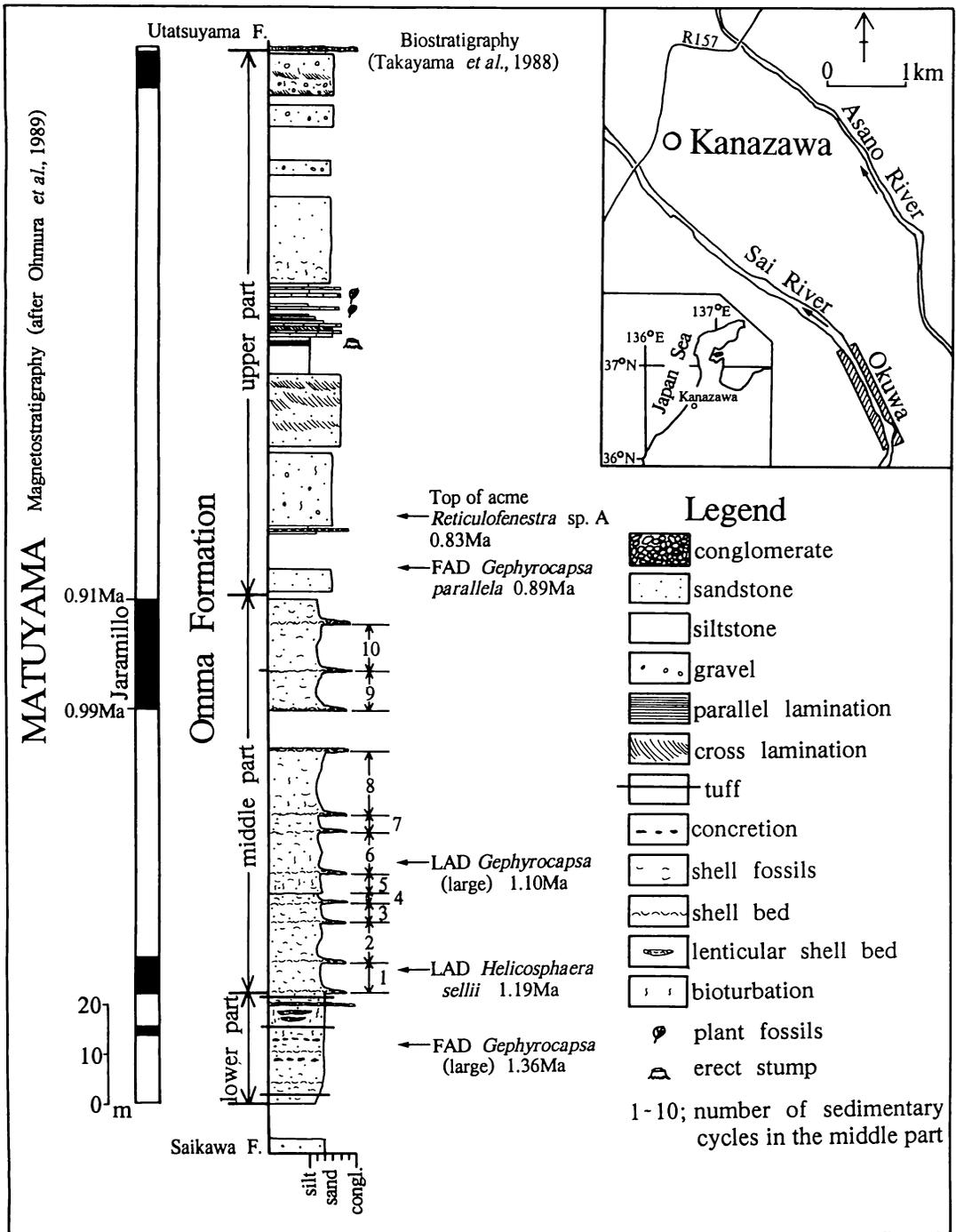
This is a part of the doctoral dissertation submitted to Kanazawa University. I am especially indebted to Prof. Kenji Konishi of Kanazawa University for his constructive

criticism and encouragement. Prof. Kiyotaka Chinzei of Kyoto University and Dr. Yasuo Kondo of Kochi University kindly helped with discussion and advice. My thanks should also be extended to Dr. Takahiro Kamiya and Prof. Toshiaki Takayama of Kanazawa University, Dr. Seiichiro Matsui of Utsunomiya University for their assistance. Emeritus Prof. Yoshio Kaseno of Kanazawa University kindly allowed me to examine his collection of molluscan fossil specimens from the Omma Formation. The manuscript was critically read by Prof. Kenji Konishi, Prof. Kiyotaka Chinzei and Dr. Seiichiro Matsui. Their suggestions and constructive criticisms are acknowledged.

#### Stratigraphic framework and geologic age

The type locality of the Omma Formation (Mochizuki, 1930) is situated at the floor of the River Saikawa, Kanazawa City, Ishikawa Prefecture, Central Japan (Figure 1). The formation overlies unconformably the Saikawa Formation (Ogasawara, 1977) and is in turn overlain unconformably by the Utatsuyama Formation (Ichihara *et al.*, 1950). The marine Saikawa Formation is mainly composed of a massive siltstone. The non-marine Utatsuyama Formation is represented by an alternation of coarse-grained sandstone, mudstone and conglomerate beds. The Omma Formation at the type section attains 210 m in thickness (Figure 1) and has a northeast-southwest strike with 10–20° dip to the northwest.

The detailed lithostratigraphy of the Omma Formation was not established until Takayama *et al.* (1988) gave a description of lithofacies of the type section. They divided the formation into two parts; the lower part consisting of bluish-gray, very fine- to fine-grained sandstone with abundant well-preserved marine molluscan fossils, and the upper part comprising four units, in ascending order: (1) brown fine- to medium-grained sandstone; (2) alternation of sand-



**Figure 1.** Columnar section of the Omma Formation at the type locality, showing biostratigraphic datum horizons established by Takayama *et al.* (1988) and paleomagnetic data by Ohmura *et al.* (1989).

stone and mudstone; (3) bluish-gray fine-grained sandstone; and (4) brown medium-grained pebbly sandstone. On the basis of the litho- and biofacies, Kitamura and Kondo (1990) subdivided the lower part into two units, and proposed a three-fold division of the formation (Figure 1). The present study deals particularly with the lithofacies and molluscan fossil associations in the lower and middle parts.

Microbiostratigraphic and magnetostratigraphic data (Hasegawa, 1979; Takayama *et al.*, 1988; Ohmura *et al.*, 1989) indicate that the Omma Formation at the type locality is of early Pleistocene age. According to Takayama *et al.* (1988), who proposed five nannofossil biohorizons in the Omma Formation at its type section, the FAD *Gephyrocapsa* (large) (1.36 Ma) is located at about 10 m above the base of the formation (Figure 1). The LAD *Helicosphaera sellii* (1.19 Ma) and LAD *Gephyrocapsa* (large) (1.10 Ma) are located in the upper part of Cycle 1 and the middle part of Cycle 6, both in the middle part of the formation, and two biohorizons, the FAD *Gephyrocapsa parallela* (0.89 Ma) and the top of acme *Reticulofenestra* sp. A (0.83 Ma), are located within the upper part of the formation (Figure 1).

A paleomagnetic study of Ohmura *et al.* (1989) established that the Omma Formation of the type locality is equated well with the Matuyama Reversed Polarity Epoch. A normal polarity horizon between the bottom of Cycle 9 and the top of the middle part is assigned to the Jaramillo Event (0.99–0.91 Ma) (Figure 1).

### **Cyclic changes of sediments and molluscan fossil associations in the middle part of the Omma Formation**

The middle part of the formation includes at least 10 cyclic changes of both sedimentary facies and molluscan fossil associations (Kitamura and Kondo; 1990). These cycles are numbered, in ascending order, from 1 to

10 (Figure 1). Thickness of each cycle is highly variable ranging from 1.5 to 11.8 m with an average of 7.0 m. The cyclicity of lithofacies and molluscan fossil associations in the middle part of the Omma Formation will be briefly reviewed in order to compare with the non-cyclic nature of the lower part.

A representative cycle exhibits a fining-upward lithologic sequence, starting from the basal shell bed, through a well-sorted fine-grained sandstone, and ending with a muddy fine- to very fine-grained sandstone. The bottom of the basal, 5 to 30 m thick, shell bed is defined with an erosional surface. The bed is usually packed with shells and terrigenous granules intermixed with sand. The shells are oriented parallel to the bedding, and occur in contact with each other to be shell-supported. The well-sorted, fine-grained sandstone, 0.5 to 1 m thick, overlies the shell bed. The sandstone appears to lack both abiogenic and biogenic sedimentary structures for the most part. In most cases, the sandstone yields a large number of articulated shells of *Felaniella usta*. The shells are dominantly oriented parallel to the bedding plane. The middle and upper portions of each cycle are composed of a muddy, fine- to very fine-grained sandstone from 0.5 m (Cycle 4) to 8 m (Cycle 8) in thickness. The sandstone yields molluscan fossils sporadically. Deep burrowers, such as *Panopea japonica*, *Barnea dilatata* and *Clementia vatheleti*, are preserved in the life position. Most other bivalves are conjoined and well-preserved, but are not in the life position. They are mostly aligned parallel to the bedding plane.

The fossil molluscs in the middle part of the formation can be grouped into 11 associations by means of combined occurrences and relative abundance of species (Kitamura and Kondo, 1990). The term "association" is here used to indicate a suite of assemblages which are similar in species composition. The characteristic and associated species of each association is shown in Table 1 along

Table 1. Molluscan fossil associations and their main constituent species in the lower and middle parts of the Omma Formation at the type locality.

Association	Characteristic species	Associated species
a. <i>Peronidia</i> Assoc.	<i>Peronidia zyoensis</i> <i>Glycymeris yessoensis</i> <i>Mercenaria stimpsoni</i> <i>Pseudamiantis tauyensis</i>	<i>Felaniella usta</i> , <i>Acila insignis</i> <i>Turritella saishuensis saishuensis</i> <i>Mizuhopecten yessoensis yokoyamae</i>
b. <i>Macoma sector</i> Association	<i>Macoma sector</i> , <i>Acila insignis</i>	<i>Felaniella usta</i> , <i>Clinocardium fastosum</i> <i>Dosinia japonica</i> , <i>Panopea japonica</i>
c. <i>Felaniella</i> Assoc.	<i>Felaniella usta</i> , <i>Acila insignis</i>	<i>Peronidia zyoensis</i> <i>Clinocardium fastosum</i> <i>Turritella saishuensis saishuensis</i>
d. <i>Clinocardium</i> — <i>Turritella</i> Assoc.	<i>Clinocardium fastosum</i> <i>Yoldia notabilis</i> <i>Turritella saishuensis saishuensis</i> <i>Acila insignis</i> , <i>Cryptomya busoensis</i> <i>Cryptonatica janthostomoides</i>	<i>Liocyma fluctuosa</i> , <i>Ennucula tenuis</i> <i>Mizuhopecten tokyoensis hokurikuensis</i> <i>Cyclocardia ferruginea</i> <i>Lucinoma annulata</i> <i>Macoma tokyoensis</i> <i>Antiplanes contraria</i> <i>Ophiodermella ogurana</i> <i>Suavodrililla declivis</i>
e. <i>Macoma tokyoensis</i> — <i>Felaniella</i> Assoc.	<i>Macoma tokyoensis</i> , <i>Felaniella usta</i>	<i>Yoldia notabilis</i> , <i>Panopea japonica</i>
f. <i>Yoldia</i> Assoc.	<i>Yoldia notabilis</i>	<i>Felaniella usta</i> , <i>Acila insignis</i> <i>Dosinia japonica</i> , <i>Panopea japonica</i>
g. Transitional Association	<i>Yoldia notabilis</i> , <i>Paphia schnelliana</i> <i>Ennucula tenuis</i> <i>Clinocardium fastosum</i>	<i>Acila insignis</i> , <i>Cryptomya busoensis</i> <i>Turritella saishuensis saishuensis</i> <i>Cryptonatica janthostomoides</i> <i>Tugurium exutum</i> , <i>Nassarius caelatus</i>
h. <i>Barnea</i> Assoc.	<i>Barnea dilatata</i>	<i>Tugurium exutum</i>
i. <i>Cycladicama</i> Association	<i>Cycladicama cumingi</i>	<i>Tugurium exutum</i> <i>Paphia schnelliana</i> <i>Barnea dilatata</i>
j. <i>Tugurium</i> — <i>Paphia</i> I Assoc.	<i>Tugurium exutum</i> , <i>Paphia schnelliana</i> <i>Nassarius caelatus</i> , <i>Yoldia notabilis</i>	<i>Saccella gordonis</i> , <i>Limopsis crenata</i>
k. <i>Tugurium</i> — <i>Paphia</i> II Assoc.	<i>Tugurium exutum</i> , <i>Paphia schnelliana</i> <i>Saccella gordonis</i> , <i>Limopsis crenata</i>	<i>Dentalium weinkauffi</i> , <i>Acila divaricata</i> <i>Glycymeris rotunda</i> <i>Saccella semataensis</i> <i>Nemocardium samarangae</i>
p. <i>Acila insignis</i> Association	<i>Acila insignis</i> , <i>Yoldia notabilis</i> <i>Solamen diaphana</i>	
q. <i>Acila divaricata</i> — <i>Limopsis</i> Assoc.	<i>Acila divaricata</i> , <i>Limopsis crenata</i>	<i>Paphia schnelliana</i> , <i>Phaxas attenuatus</i>
r. <i>Anadara</i> — <i>Clinocardium</i> Association	<i>Anadara amicula</i> <i>Clinocardium fastosum</i> <i>Yoldia notabilis</i>	<i>Turritella saishuensis saishuensis</i> <i>Acila insignis</i> , <i>Mya japonica</i> <i>Cryptonatica janthostomoides</i>

water regime	cold water		transitional water	warm water		
low tide mark	a. <i>Peronidia</i> Assoc. b. <i>Macoma sector</i> Assoc. r. <i>Anadara - Clinocardium</i> Assoc.	c. <i>Felaniella</i> Assoc. d. <i>Clinocardium-Turritella</i> Assoc.		h. <i>Barnea</i> Assoc.	i. <i>Cycladicama</i> Assoc.	
20-30m		e. <i>Macoma tokyoensis - Felaniella</i> Assoc. f. <i>Yoldia</i> Assoc.	g. Transitional Assoc.			j. <i>Tugurium - Paphia I</i> Assoc.
50-60m						q. <i>Acila divaricata - Limopsis</i> Assoc.
100-120m		p. <i>Acila insignis</i> Assoc.				k. <i>Tugurium - Paphia II</i> Assoc.

Figure 2. Relationship between the molluscan fossil associations and environmental conditions in terms of water depth and water regime.

with three associations in the lower part. Relationships between these associations and such environmental conditions as water depth, water regime and sediment are summarized in Figure 2. The environmental characters of the associations relative to the nature of the sea water (cold-, intermediate- and warm-water) and approximate water depth of habitat are inferred from information available from the living species (Geographical distribution: Kuroda and Habe, 1952, Higo, 1973; Bathymetry: Oyama, 1952, 1973). Based on the geographical distribution along the Pacific coast shelf area, the term "cold-water element" here refers to those species living in the area north of 35°N and "warm-water element" to those south of 35°N. Species dwelling in both areas are grouped as the "intermediate element".

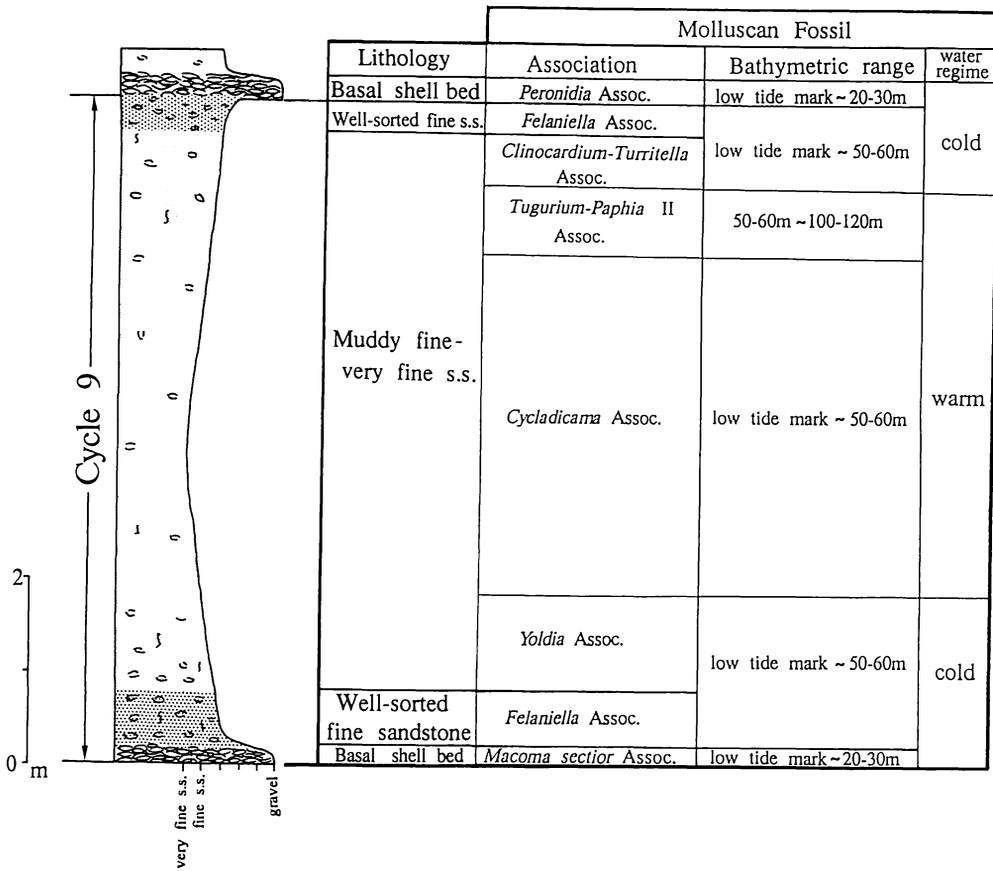
In most cycles, the vertical change in molluscan associations indicates that environment had changed from the cold-water, upper sublittoral zone through the warm-water, lower sublittoral zone to the cold-water, upper sublittoral zone as observed typically in Cycle 9 shown in Figure 3. This increase of water depth is concordant with a climatic

change from cold to warm. Based on molluscan associations, biostratigraphic as well as paleomagnetic data, the maximum amplitude of water-depth fluctuation is estimated to be 50 m and the periodicity 28,000 years on the average. These characteristic temporal and cyclic changes of oceanographic conditions can be best explained by invoking glacio-eustatic sea-level and paleotemperature changes (Kitamura and Kondo, 1990).

#### Lithofacies and molluscan fossil associations of the lower part of the Omma Formation

##### Lithofacies

The 25 m-thick lower part of the Omma Formation which was accumulated during a 0.16 m.y. time interval from 1.36 to 1.2 Ma consists of a bluish-gray, partly brown, fine-grained sandstone, except for the basal part at Horizon 1 (Figure 4), where it is composed of a silty, very fine-grained sandstone with 30% mud content. Shells occur scatteringly throughout most of the lower part. Some are concentrated to form shell beds. However, those brown sandstones occurring at both



**Figure 3.** Stratigraphy of Cycle 9, showing distribution of the molluscan fossil associations and their bathymetric ranges and water regimes.

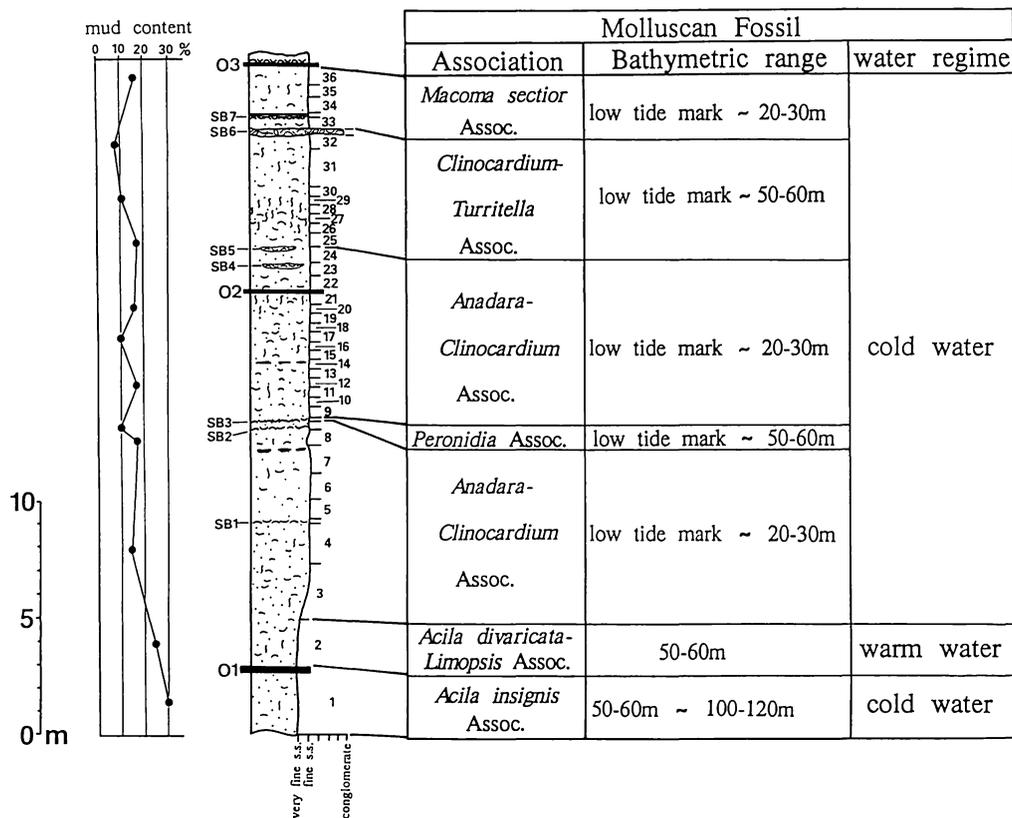
Horizon 5 and 24 are apparently barren of molluscan fossils. Muddy tubular burrows are often observed. There occur three white tuff layers of between 20 and 30 cm in thickness, numbered O1, O2, and O3 in upward sequence (Hasegawa, 1979), and two 10-20 cm-thick concretion-bearing layers at Horizon 7 and 14 (Figure. 4).

Seven shell beds are observed in the lower part, and are here named SB1, SB2, SB3, SB4, SB5, SB6 and SB7, in ascending order. The dominant alignment of shells is parallel to the bedding plane and shells are supported by themselves. In the lower part of the Omma Formation, neither cyclic changes as in the middle part nor any regular trend of vertical change of lithofacies can be observed in sedi-

ments lying between these shell beds. These shell beds in the lower part have their origin apparently different from that of the basal shell beds occurring in the middle part. Four shell beds (SB4, 5, 6 and 7) appear to be formed by storms, because they have sedimentary features—a lenticular shape with a sharp erosional base and the overlying massive or laminated layer—which are typical of the storm-generated ones (Kreisa, 1981). The formational processes of the other three beds are uncertain.

**Faunal associations**

Stratigraphic distribution of the molluscan fossils in the lower part was described with the methods applied for the middle part (Kitamura and Kondo, 1990). Most bivalves



**Figure 4.** Stratigraphic column of the lower part of the Omma Formation, showing mud contents, horizons and distribution of molluscan fossil associations, accompanied with bathymetric range and water regime of each association. For explanation of the sediments, see legend in **Figure 1**. O1, O2 and O3: tuff layers. SB1-7: shell bed.

are conjoined, except for those in the SB1, 4, 5, 6 and 7. They are not in life position. This indicates that the shells were not transported after death for any appreciable distance from their original habitats. In the SB1, 4, 5, 6 and 7, shells are poorly preserved and the abundant occurrence of fragmental debris without any admixture of articulated individuals suggests their transportation for a considerable distance from original habitats. Therefore, they are excluded from the following discussion.

The molluscan fossils in the lower part of the Omma Formation can be grouped into six associations by means of associated occurrences and relative abundance of species (Figure 5). Table 1 shows the species composi-

tion of these associations. Three associations (*Peronidia*, *Clinocardium-Turritella* and *Macoma sector* Associations) are recognized in the middle part. A detailed description of these associations has been given in Kitamura and Kondo (1990). Three other associations, *Acila insignis*, *Acila divaricata-Limopsis* and *Anadara-Clinocardium* Associations, are restricted to the lower part. Characteristic and subordinate species of these associations are described and discussed below. Paleoenvironmental condition of each association is inferred from the distributional data of living species occurring in the association.

#### *Acila insignis* Association

This association is composed of *Acila in-*

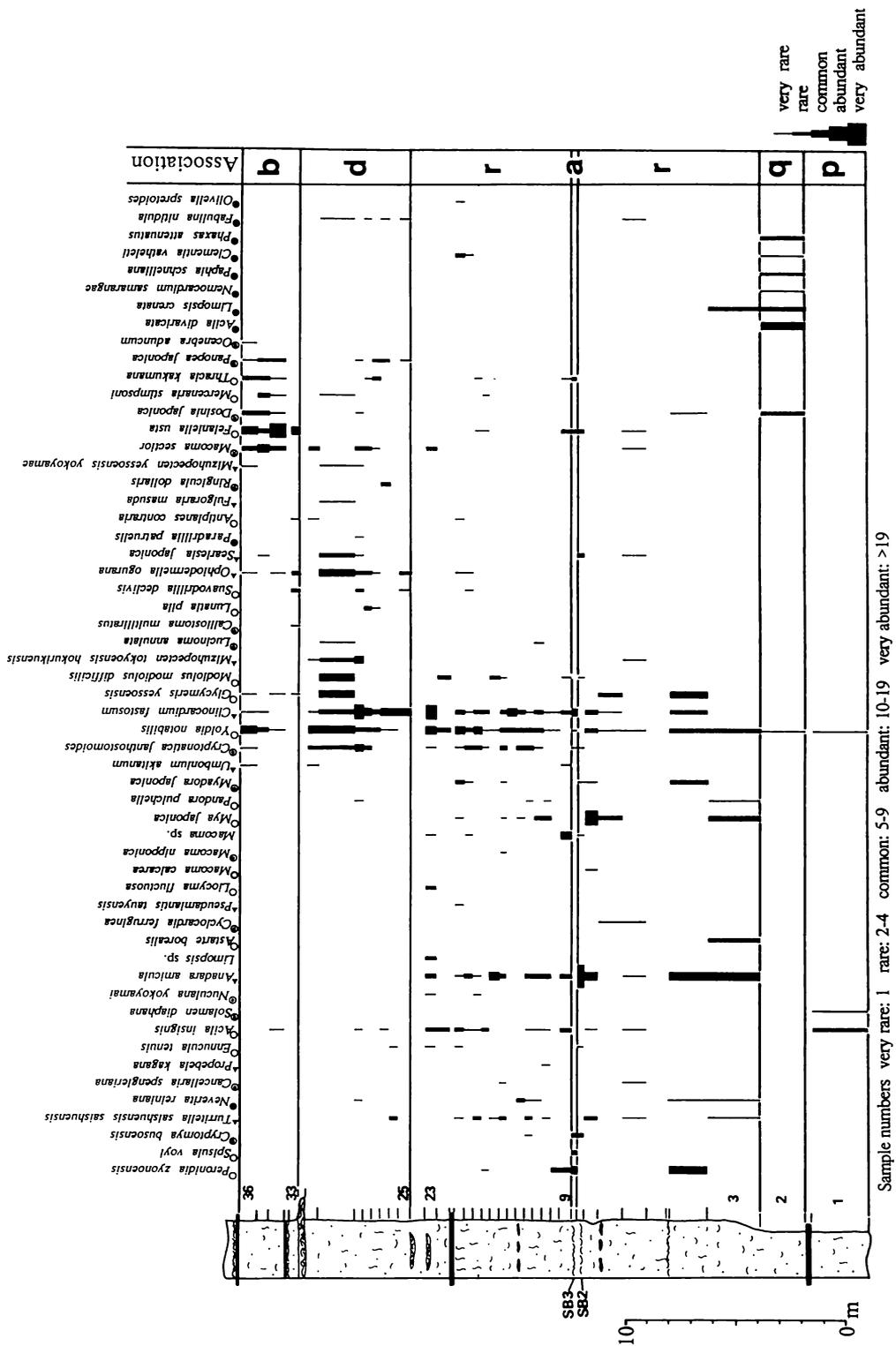


Figure 5. Stratigraphic distribution of molluscan species in the lower part of the Omma Formation. a : *Peronida* Assoc., b : *Macoma* sector Assoc., d : *Clinocardium-Turritella* Assoc., p : *Acila insignis* Assoc., q : *Acila divaricata-Limopsis* Assoc., r : *Anadara-Clinocardium* Assoc. ○ : cold-water species, ● : intermediate species, ▲ : extinct species. Also refer to legend in Figures 1 and 4.

*signis*, *Yoldia notabilis* and *Solamen diaphana* (Table 1). They occur very sporadically in a silty, very fine-grained sandstone at Horizon 1 (Figure 5). Most of the shells are disarticulated and randomly oriented.

The living species in this association presently inhabit cold-water areas between 20 and 120 m deep. Takayama *et al.* (1988) described that the sandstone which yields this association abundantly contains a foraminifer, *Bulimina marginata*. According to Akimoto and Hasegawa (1989), the upper bathymetric limit of this species in the Japan Sea is in the middle sublittoral zone (from 45 to 80–90 m depth). Thus the upper limit of the habitat of the *Acila insignis* Association may be 45 m and the bathymetric range of this association is assigned to the lower sublittoral zone (Figure 2).

#### *Acila divaricata*-*Limopsis* Association

This association is confined to the 1.5 m-thick, fine-grained sandstone at Horizon 2 (Figure 5). Characteristic species of the association are *Acila divaricata* and *Limopsis crenata*, which are associated with *Paphia schnelliana* and *Phaxas attenuatus* (Table 1). All three individuals of *P. attenuatus* are found to have conjoined valves and show a vertical, posterior-up orientation. They seem to be preserved in life position. Other shells are dominantly disarticulated and occur sporadically.

According to the ecological data available from the living species, *A. divaricata* and *L. crenata* inhabit waters between 50–60 and 100–120 m deep and *P. attenuatus* from the low tide mark to 50–60 m depth, all in warm-water areas. Therefore, this association is interpreted to have lived in water about 50–60 m deep near the boundary between the lower and upper sublittoral zones (Figure 2).

#### *Anadara*-*Clinocardium* Association

This association occurs at two horizons, Horizon 3~SB2 and Horizon 9~23, in a fine-grained sandstone (Figure 5). Characteristic species of this association include *Anadara amicula*, *Clinocardium fastosum*

and *Y. notabilis*. In addition, *Turritella saishuensis*, *A. insignis*, *Mya japonica*, *Cryptonatica janthostomoides* and *Myadora japonica* are found (Table 1). *A. amicula* forms a loosely packed shell bed (SB2) of 15 to 20 cm in thickness, in which shells, including many conjoined and lightly abraded individuals, are randomly oriented. These well-preserved shells appear to be autochthonous as a whole. Closely packed shells, possibly due to wave and current actions, are, however, encountered in some part of the bed. *Mya japonica* is usually found in life position, with its shells still articulated and well-preserved. The other shells are oriented horizontally to the bedding plane.

Although *A. amicula* is an extinct species, living species of the genus are generally known from embayments shallower than 20–30 m depth. Judging from this and other bathymetric records of living representatives of this association, the association is considered to have lived most probably between a low tide mark and 30 m depth in an embayment influenced by cold-water (Figure 2).

### Environmental changes during the deposition of the lower part

Among the six molluscan fossil associations recognized in the lower part of the formation, the *Acila divaricata*-*Limopsis* Association is composed mainly of warm-water elements, and the other associations are dominated by cold-water elements (Figure 4). The temporal change shown by these associations indicates that the study area was essentially affected by cold water nearly throughout the deposition of the lower part, except for a short interval at Horizon 2 when warm water flowed into this area.

Molluscan fossils change upwards from the *Acila insignis* Association (lived in the lower sublittoral zone), through the *Acila divaricata*-*Limopsis* Association (lived at 50–60 m depth) to the *Anadara*-*Clinocardium* Association (lived from the low tide mark to 20–30

m depth) from Horizons 1 to 3 (Figure 4). This change indicates that the water depth decreased gradually in the study area.

In the sequence above Horizon 3, change of water depth can not be inferred directly from the molluscan associations, because the molluscan associations occurring there suggest no bathymetric differences (Figure 4). However, the concentrated occurrence of storm-generated shell beds in this part of the sequence indicates that water depth decreased during the deposition of this interval. Four storm-generated shell beds are observed only in the horizon between Horizon 23 and 34 (Figure 4). Kreisa (1981) discussed that the effect of a storm at the sediment-water interface should be less intense in deep water than in shallow water, and if storms are assumed to occur randomly over a long period of time, then the number of storm deposits in strata deposited during a given time interval would be expected to increase with decreasing water depth. Thus, it is interpreted that the depositional depth of the four horizons marked by storm-generated shell beds was probably shallower than that of the rest of the lower sequence. In short, vertical change of molluscan associations and stratigraphical position of storm-generated shell bed suggest a shallowing-upward trend for the major part of the lower sequence, except for its basal portion.

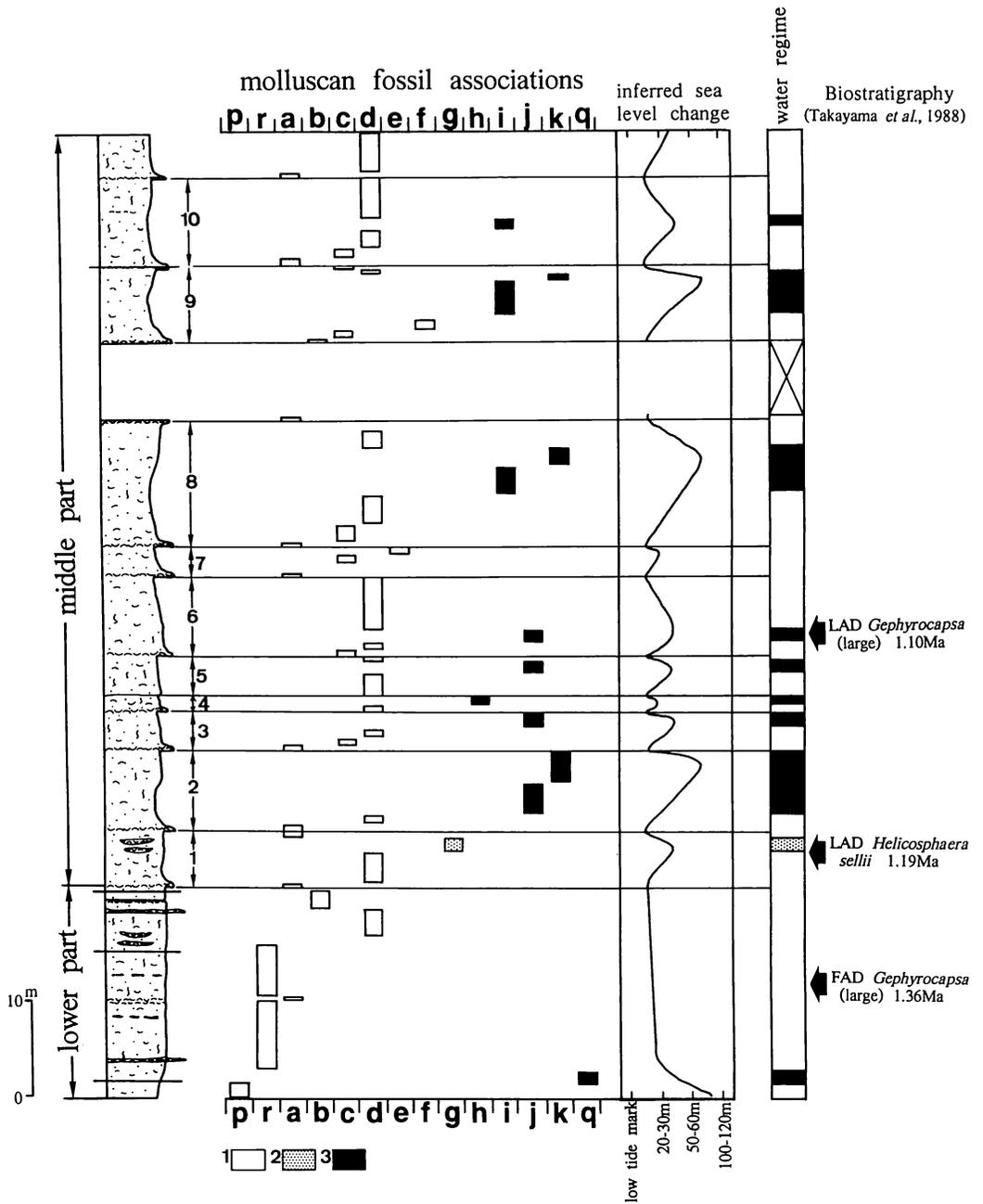
**Transition of paleoenvironment at the boundary between the lower and middle parts of the Omma Formation**

Oceanographic and climatic conditions deduced from the sedimentological and paleoecological data which were documented in the preceding sections suggest that there is a remarkable difference in the pattern of environmental changes between the lower and middle parts of the Omma Formation.

At least 10 periods of glacio-eustatic sea-level fluctuations, which have an amplitude of up to 50 m and the estimated periodicity of 28,000 years on the average, are recognized in

the middle part. Although, as compared with the middle part, the sedimentary environment during the deposition of nearly all the lower part was shallower up to a water depth of 20–30 m under cold-water, the record of glacio-eustatic sea-level fluctuations as seen in the middle part can not be observed in this part. The boundary age between the lower and middle parts is estimated to be 1.2 Ma, based on biostratigraphic data (Takayama *et al.*, 1988). Hence, a marked change of paleoenvironment must have taken place at that time.

Since oxygen isotope data base for the early Pleistocene Epoch is relatively limited, interpretations of the isotope data in terms of global eustasy are as yet not well established. The oxygen isotope signals, however, clearly fluctuate during the time interval coeval with the deposition of the lower part of the Omma Formation, between about 1.36 and 1.2 Ma (*e.g.*, Williams *et al.*, 1988). Thus, there can be little doubt that climatic changes correlative with the glacial-interglacial cycles must have occurred in the interval representing the lower part of the Omma Formation. A period of about 0.16 m.y. during the deposition of the lower part is a time span long enough to record several sea-level fluctuations with the periodicity of a few tens of thousand years. Furthermore, the molluscan composition suggests that most horizons in the lower part were deposited in depths shallower than 20–30 m (Figure 4). In such shallow-environments, changes of sea level even on the order of 10 m should bring some variations in lithofacies as well as fossil molluscan associations. As the original record was not likely to have been modified or lost by reworking and bioturbation, the absence of any evidence for a distinct glacio-eustatic sea-level fluctuation in the lower part appears to suggest that the amplitude of sea-level fluctuation was too small to be detected with the kind of method adopted in the present study. This may imply that the amplitude of glacio-eustatic sea-level changes increased beginning at



**Figure 6.** Vertical distribution of the molluscan fossil associations and changes in marine climate and inferred sea-level during the deposition of the lower and middle parts of the Omma Formation. Biostratigraphic datums are based on Takayama *et al.* (1988). 1: cold-water associations and cold water, 2: transitional association and transitional water, 3: warm-water associations and warm water. For explanation of the sediments, see legend in **Figure 1**. Associations a-k and p-r are the same as those in **Figure 2** and Table 1.

about 1.2 Ma (Figure 6).

The occurrence of the warm-water faunal association, including the transitional association, indicates that at least nine periods of influx of warm water took place in the study area between 1.2 and 0.9 Ma, whereas warm water flowed only once between 1.36 and 1.2 Ma (Figures 1, 6). This means that frequent influxes of warm water began at 1.2 Ma. Based on paleoecologic studies, Ogasawara (1981, 1983) pointed out that the Japan Sea was connected with the Pacific through the present-day Tsushima Strait area during early Pleistocene time and warm water flowed from south through the Strait into the Japan Sea. According to Honza (1978), the area has been tectonically rather quiet during the Pliocene and Pleistocene. Therefore, it is not possible to relate the frequent influxes of warm water to some tectonic movements around the Strait. One possible explanation for the frequent influxes of warm water is that sea levels during the interglacial stages between 1.2 and 0.9 Ma probably stood high compared with the previous interglacial stages, so that warm water could invade into the Japan Sea during every interglacial stages since 1.2 Ma.

Jansen *et al.* (1988) recently presented records of climatic and oceanographic changes in the Norwegian Sea during the last 2.8 m.y., based on sedimentologic, isotopic and magnetostratigraphic investigations of deep-sea cores. According to them, glaciations were mild between 2.0 and 1.2 Ma in Scandinavia, and "a transition toward larger glacials took place during the period from 1.2 to 0.6 Ma", giving rise to warmer interglacials owing to increasing influx of temperate surface waters. In the North Pacific, ice-rafted detritus in the deep-sea sediment record indicates the initiation of cooling at about 1.2 Ma (Kent *et al.*, 1971).

These studies suggest that oceanographic and climatic conditions caused by glacial-interglacial changes shifted at around 1.2 Ma. This age fits well the boundary age between the lower and middle parts of the Omma

Formation. It is thought that the paleoenvironmental transition which was found at the boundary may be closely related to the intensification of glaciation in Europe and North America. Such a transition as recorded in the Omma Formation should be recognized in the contemporaneous marine strata containing the Omma-Manganji Fauna elsewhere in the circum-Japan Sea region.

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Ishikawa 石川, Hokuriku 北陸, Omma 大桑, River Sai 犀川, Kanazawa 金沢, Saikawa 犀川, Utatsuyama 卯辰山

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大桑層における 1.2 Ma を境とする古環境の変化: 大桑層の古環境は, 下部—中部の境界 (年代 1.2 Ma) で著しく変化した。大桑層中部には, 氷河性海水準変動 (最大振幅 50 m, 平均周期 28,000 年) に起因する堆積サイクルの繰り返しと貝化石群集の周期的変化が見られる。一方, 岩相・貝化石群集から, 下部の堆積環境は, 堆積期間 (少なくとも 16 万年間) のほとんどを通じて, 水深 30 m より浅い海域であったと推定される。このような浅海域であったにもかかわらず, 下部には中部に見られるような氷河性海水準変動の記録が観察されない。このことは, 1.2 Ma を境としてそれ以後, 氷河性海水準変動の振幅が増大したことを示唆すると考えられる。暖流系貝化石群集に示される暖流の流入は, 大桑層中部 (堆積期間は 30 万年間) では少なくとも 9 回であったのに対して, 下部堆積時には 1 回しかなかった。この暖流流入の頻繁化も 1.2 Ma 以降の氷河性海水準変動の振幅増大に原因があると思われる。この年代は, ヨーロッパや北アメリカで氷河作用が強化され始めた時期に一致する。すなわち, 氷河作用の強化と大桑層に記録されている変動パターンの変化とは密接な関係があると推論される。

北村晃寿

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**919. REDESCRIPTION AND MODE OF OCCURRENCE OF  
*NIPPONOCLAVA YOKOYAMAI* (SHIKAMA, 1954)  
(CLAVAGELLIDAE: BIVALVIA) FROM THE  
PLIO-PLEISTOCENE WARM-WATER FAUNA IN JAPAN\***

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**Abstract.** *Nipponoclava yokoyamai* (Shikama), a burrowing clavagellid, is re-described on the basis of 25 well-preserved specimens, newly collected from the upper Pliocene and lower Pleistocene Ukari, Ananai and Takanabe Formations distributed along the Pacific coast of central and southwestern Japan. This species has been known previously only from three imperfect specimens. It is very similar to *Nipponoclava gigantea* (Sowerby), but is distinguished in having a strong contraction between the shell sheath and the anterior plate, and in having a morph with a greatly depressed oval outline in the sheath cross section. In the Ukari Formation, *N. yokoyamai* occurs autochthonously in strongly bioturbated silty sands that contain sporadically molluscan fossils indicative of upper-sublittoral, warm-water condition.

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**Key words.** Bivalvia, Clavagellidae, Japan, *Nipponoclava yokoyamai*, Plio-Pleistocene, warm-water fauna.

### Introduction

Clavagellids are tube-dwelling bivalves enclosing themselves in an adventitious calcareous envelope which is embedded in soft sediments or attached to hard substrata. Clavagellids first appeared in the upper Cretaceous in eastern North America, Europe, northern Africa, and southern India (Pojeta and Sohl, 1987). They subsequently extended their geographic range through the Tethys seaway (Smith, 1962b) and now are distributed in the Indo-Western Pacific region, from southern Japan to southern Australia and to southeastern Africa, and also in central part of the Mediterranean Sea (Smith, 1976). There are some 50 (Smith,

1962a) or 60 (Savazzi, 1982a) valid species.

In Japan, four endemic species of clavagellids occur in Miocene to Holocene sediments.

*Nipponoclava gigantea* (Sowerby) is a Holocene species distributed in southwestern Japanese waters influenced by the warm Kuroshio Current.

*Nipponoclava yokoyamai* (Shikama) occurs in the late Pliocene and early Pleistocene warm-water faunas distributed along the Pacific coast of central and southwestern Japan. This species has been known previously only from three imperfect specimens.

*Nipponoclava kanazawaensis* (Omura) is known only in the middle Miocene Sunakozaka Formation, central Japan (Omura, 1969; Ogasawara, 1976), and occurs in association with warm-water molluscs (Ogasawara, 1976).

*Stirpulina ramosa* (Dunker) is a late Pleis-

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\*Received December 10, 1990; accepted April 10, 1991

tocene (Shikama, 1954) to Holocene species living in southwestern Japanese waters influenced by the Kuroshio Current.

Yokoyama (1926b) described *Clavagella japonica* Yokoyama from the lower Pleistocene Shibikawa Formation of northern Japan, but Habe (1952) considered this species to be an annelid tube.

The aim of this study is to redescribe *Nipponoclava yokoyamai* (Shikama) on the basis of newly collected, 25 well-preserved specimens, and to document its mode of occurrence.

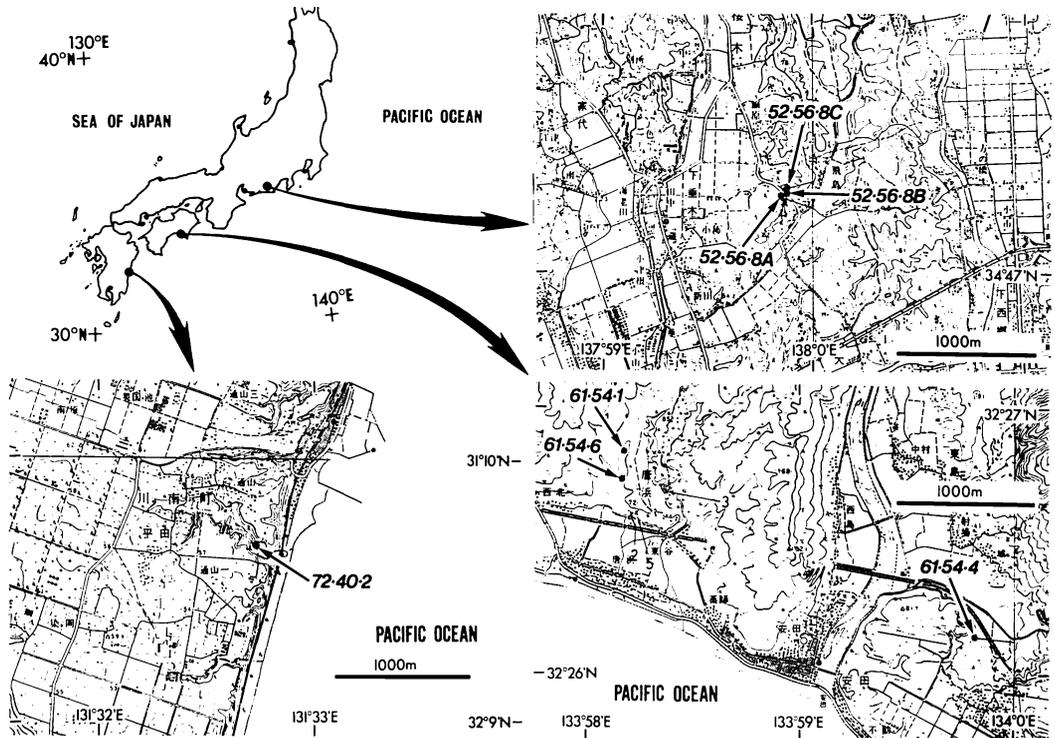
This study adopts the morphological terminology for clavagellids used by Pojeta and Sohl (1987) who followed Savazzi's (1982a) suggestion and used the term crypt for all the calcareous hard parts of clavagellids. The

word shell is limited to the bivalved juvenile hard parts.

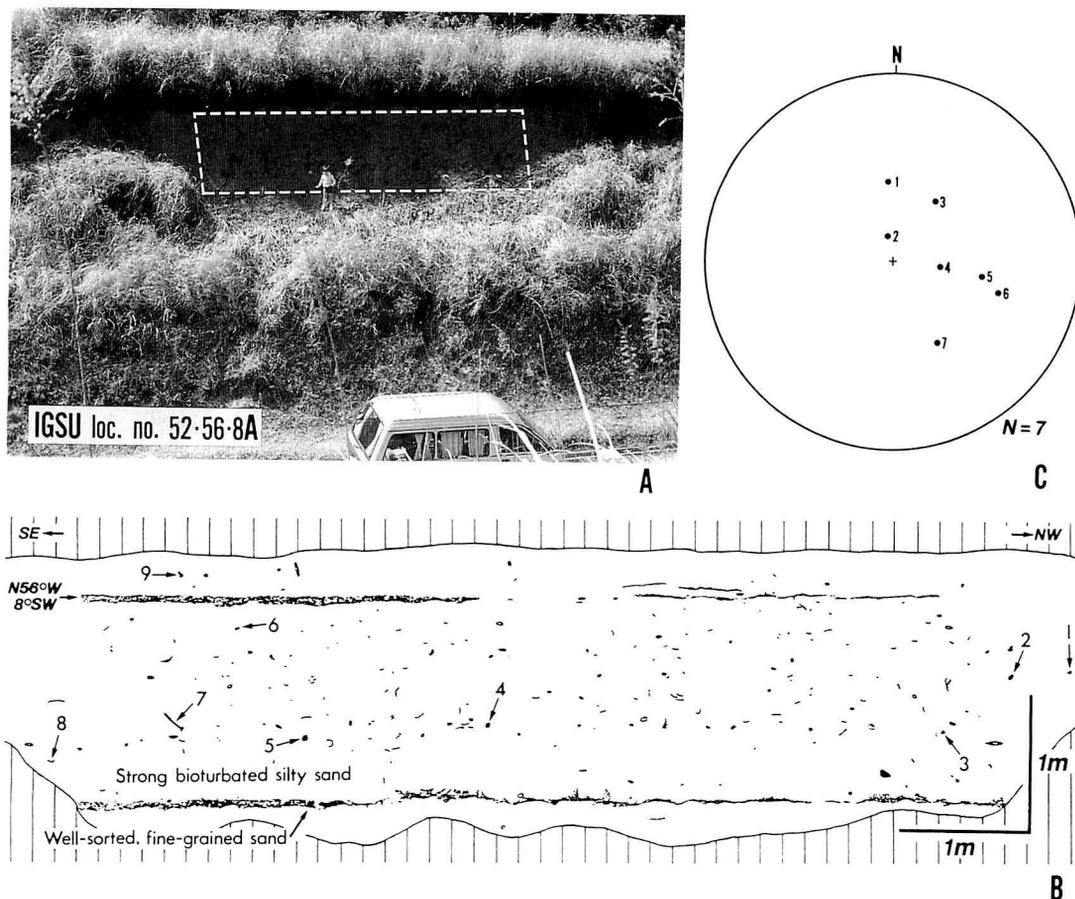
The specimens used in this study have repository numbers prefixed with IGSU (Institute of Geosciences, Shizuoka University) and UMUT (University Museum, University of Tokyo). The locality numbers accompanying the specimens are also prefixed with IGSU.

### Collecting localities

Specimens examined in this study are collected from the upper Pliocene and lower Pleistocene Ukari, Ananai and Takanabe Formations on the Pacific coast of central and southwestern Japan (Figure 1). The molluscan fossils of the Ukari and Ananai Forma-



**Figure 1.** Map showing location of collecting localities of *Nipponoclava yokoyamai*. IGSU loc. nos. 52-56-8A, 52-56-8B and 52-56-8C, plotted on 1 : 25,000-scale topographic map of Japan, Quadrangles "Yamanashi" and "Kakegawa," Geographical Survey Institute. IGSU loc. nos. 61-54-1, 61-54-4 and 61-54-6, plotted on 1 : 25,000-scale topographic map, Quadrangles "Aki" and "Nahari." IGSU loc. no. 72-40-2, plotted on 1 : 25,000-scale topographic map, Quadrangles "Kawaminami" and "Takanabe."



**Figure 2.** Mode of occurrence of fossil *Nipponoclava yokoyamai* in the upper Pliocene Ukari Formation. **A** and **B**, Outcrop photo (**A**) and sketch (**B**) of IGSU loc. no. 52-56-8A. A quadrangle area circumscribed by white dashed line of **A** indicates sketch area of **B**. The strike of the stratum is nearly equal to that of the outcrop surface, so that sandstone beds are seemingly horizontal on the outcrop. **B**-1-9, *Nipponoclava yokoyamai* (Shikama); 1, IGSU M020; 2, IGSU M021 (see **Figure 4-3**); 3, IGSU M022; 4, IGSU M023 (see **Figure 3-1**); 5, IGSU M024; 6, IGSU M025; 7, IGSU M026 (see **Figures 2-C-2, 3-3, 6-3**); 8, IGSU M027; 9, missing during collection. **C**, anterior-posterior axes of *Nipponoclava yokoyamai* (Shikama) at IGSU loc. nos. 52-56-8A (1, 2), 52-56-8B (3-5) and 52-56-8C (6, 7). Upper hemisphere projection. Each axis is corrected from tectonic tilt (dip, 8°SW; strike, N62°W). All the measurable specimens show a normal position with their siphonal opening directing upward and anterior plate downward against the bedding plane. 1, IGSU M027 (see **Figure 4-2a-2b**); 2, IGSU M026 (see **Figures 2-B-7, 3-3, 6-3**); 3, IGSU M029 (see **Figure 3-2**); 4, IGSU M030 (see **Figures 3-6, 6-2**); 5, IGSU M031; 6, IGSU M033 (see **Figures 3-5, 4-1a-1b**); and 7, IGSU M034.

tions at the localities listed below occur sporadically in dark gray, strongly bioturbated silty sands.

IGSU loc. no. 52-56-8A. — A northeast-facing roadcut (**Figures 2-A, 2-B**) at Asuka, Kakegawa City, Shizuoka Prefecture, Pacific side of central Japan. Latitude 34°47'18"N, longitude 137°59'52"E. Ten specimens of *N.*

*yokoyamai* occurring in the lowermost part of the upper Pliocene Ukari Formation of the Kakegawa Group were collected.

IGSU loc. no. 52-56-8B. — A southwest-facing roadcut occurring at Asuka on the opposite side of the road from IGSU loc. no. 52-56-8A. Four specimens of *N. yokoyamai* were obtained from the lowermost

part of the upper Pliocene Ukari Formation of the Kakegawa Group.

IGSU loc. no. 52-56-8C. — A northeast-facing cut at Asuka on the opposite side of a low ridge from IGSU loc. no. 52-56-8B. Five specimens of *N. yokoyama* occurring in the lowermost part of the upper Pliocene Ukari Formation of the Kakegawa Group were collected.

IGSU loc. no. 61-54-1. — A cliff in a small valley (Ikenotani valley), about 400 m upstream of the valley entrance, Tonohama, Aki City, Kochi Prefecture, Pacific side of southwestern Japan. Latitude 32°26'49"N, longitude 133°58'11"E. One specimen of *N. yokoyamai* was obtained from the upper Pliocene Ananai Formation of the Tonohama Group.

IGSU loc. no. 61-54-4. — A cut on east-facing hill slope, about 1,100 m northeast of the Yasudagawabashi bridge, Yasuda-machi, Aki-gun, Kochi Prefecture, Pacific side of southwestern Japan. Latitude 32°26'9"N, longitude 133°59'49"E. Three specimens of *N. yokoyamai* were collected from the upper Pliocene Ananai Formation of the Tonohama Group.

IGSU loc. no. 61-54-6. — A cliff in a small valley (Ikenotani Valley), about 250 m upstream from the valley entrance, Tonohama, Aki City, Kochi Prefecture, Pacific side of southwestern Japan. Latitude 32°26'43"N, longitude 133°58'11"E. One specimen of *N. yokoyamai* occurring in the upper Pliocene Ananai Formation of the Tonohama Group was collected.

IGSU loc. no. 72-40-2. — Sand blocks dropped from a cliff into a small valley, about 1,000 m southwest of Toriyama fishing port, Toriyama, Kawaminami-machi, Koyu-gun, Miyazaki Prefecture, on the Pacific side of southwestern Japan. Latitude 32°9'41"N, longitude 131°32'44"E. Two specimens of *N. yokoyamai* were collected from fine-grained sand blocks of the lower Pleistocene part of the upper Pliocene and lower Pleistocene Takanabe Formation of the Miyazaki Group.

### Mode of occurrence

I have examined 19 specimens of *Nipponoclava yokoyamai* collected at IGSU loc. nos. 52-56-8A, 52-56-8B and 52-56-8C. The strata at these localities consist of dark gray, massive silty sands intercalated with well-sorted, fine-grained sands, of the lowermost part of the upper Pliocene Ukari Formation. The silty sand beds are strongly bioturbated and molluscan fossils occur sporadically (Figure 2). *Nipponoclava yokoyamai* is considered to occur autochthonously, because the anterior-posterior axes of measurable specimens dip steeply from the bedding plane (commonly more than 45 degrees: Figure 2-C) and they always show the natural shell orientation of siphonal opening pointing upward and anterior plate downward (Figure 3). In the natural environment, *Penicillus*, a burrowing clavagellid genus like *Nipponoclava*, usually lies embedded vertically in a silty sand with the anterior plate lowermost and the siphonal opening slightly above the sediment surface (Savazzi, 1982b; Purchon, 1956, 1960; Pojeta and Sohl, 1987). *Nipponoclava* is considered to live or have lived in the same manner as *Penicillus*. Okutani and Soyama (1987) illustrated a living *Nipponoclava gigantea* (Sowerby) as oriented vertically in the substrate with the opening of the siphonal sheath projecting above the sediment surface. *Nipponoclava yokoyamai* is, therefore, considered to have lived embedded nearly vertically in sediment with the anterior plate lowermost and the siphonal opening projecting above the sediments. The reason why no fossil is oriented exactly normal to the bedding plane (Figure 2-C) is likely to be attributed to the disturbance caused by such biologic agents as bioturbators, predators, scavengers, as inferred from strong bioturbation in the fossil-bearing silty sands. Therefore, these clavagellid fossils are considered to have been preserved essentially *in situ* and show the position near to their probable life orientation.

The following molluscan fossils occur in the localities: *Acila* sp., *Anadara suzukii* (Yokoyama), *Glycymeris totomiensis* Makiyama, *Amusiopecten praesignis* (Yokoyama), *Chlamys satoi* (Yokoyama), *Lutraria* sp., *Phaxas attenuatus* (Dunker), *Pitar* sp., *Phasia schnelliana* (Dunker), *Callista chinensis* (Holten), *Clementia* sp., *Panopea japonica* Adams, *Tristichotrochus* sp., *Onustus exutus* (Reeve), *Glossaulax hagenoshitensis* (Shuto), *G. hyugensis* (Shuto), *Cryptonatica adamiana* (Dunker), *Tonna luteostoma* (Küster), *Zeuxis* sp., *Fusinus* sp., *Lophioturris leucotropis* (Adams et Reeve), and *Architectonica maxima* (Philippi). They indicate upper sublittoral, warm-water condition, and constitute components of the Pliocene and early Pleistocene warm-water molluscan faunas, collectively called the Kakegawa fauna (Chinzei, 1986). This fauna occurs in strata distributed along the Pacific coast of central and southwestern Japan.

Bivalve fossils that consist mainly of infaunal species show a high rate of articulation. Excluding *Nipponoclava yokoyamai*, 129 bivalve specimens occur at Locality 52-56-8A (Figures 2-A, 2-B), of which 52 are articulated. Valves of many articulated specimens are closed, whereas their shell orientation is randomly arranged. Nearly all of the articulated bivalves, excluding *N. yokoyamai*, seemingly do not occur in their life orientations. As *N. yokoyamai*, they are also likely to have been reoriented by disturbance caused by the biologic agents. These bivalves have commonly an elliptical to circular outline that might be more easily disturbed entirely from their life orientation by biologic agents than *N. yokoyamai*. Gastropods are generally rare in occurrence and also show random shell orientation.

The molluscan fossils of the three localities are considered to be a parautochthonous assemblage which is composed of autochthonous specimens reworked to some degree but not transported out of the original life habitat (Kidwell *et al.*, 1986).

### Systematic paleontology

Class Bivalvia Linnaeus, 1758

Subclass Anomalodesmata  
Dall, 1889

Order Pholadomyoidea  
Newell, 1965

Superfamily Clavagellacea  
d'Orbigny, 1844

Family Clavagellidae  
d'Orbigny, 1844

Genus *Nipponoclava* Smith, 1976

*Type species.*—*Aspergillum giganteum* Sowerby, 1888, by original designation. Recent, southwestern Japan.

*Diagnosis.*—Both large bivalved juvenile shells becoming fused to elongate sheath. Sheath circular to ovoid in transverse section with well-developed siphonal collars at the posterior end. Enlarged anterior plate bearing many rows of tubules that may be bifurcated.

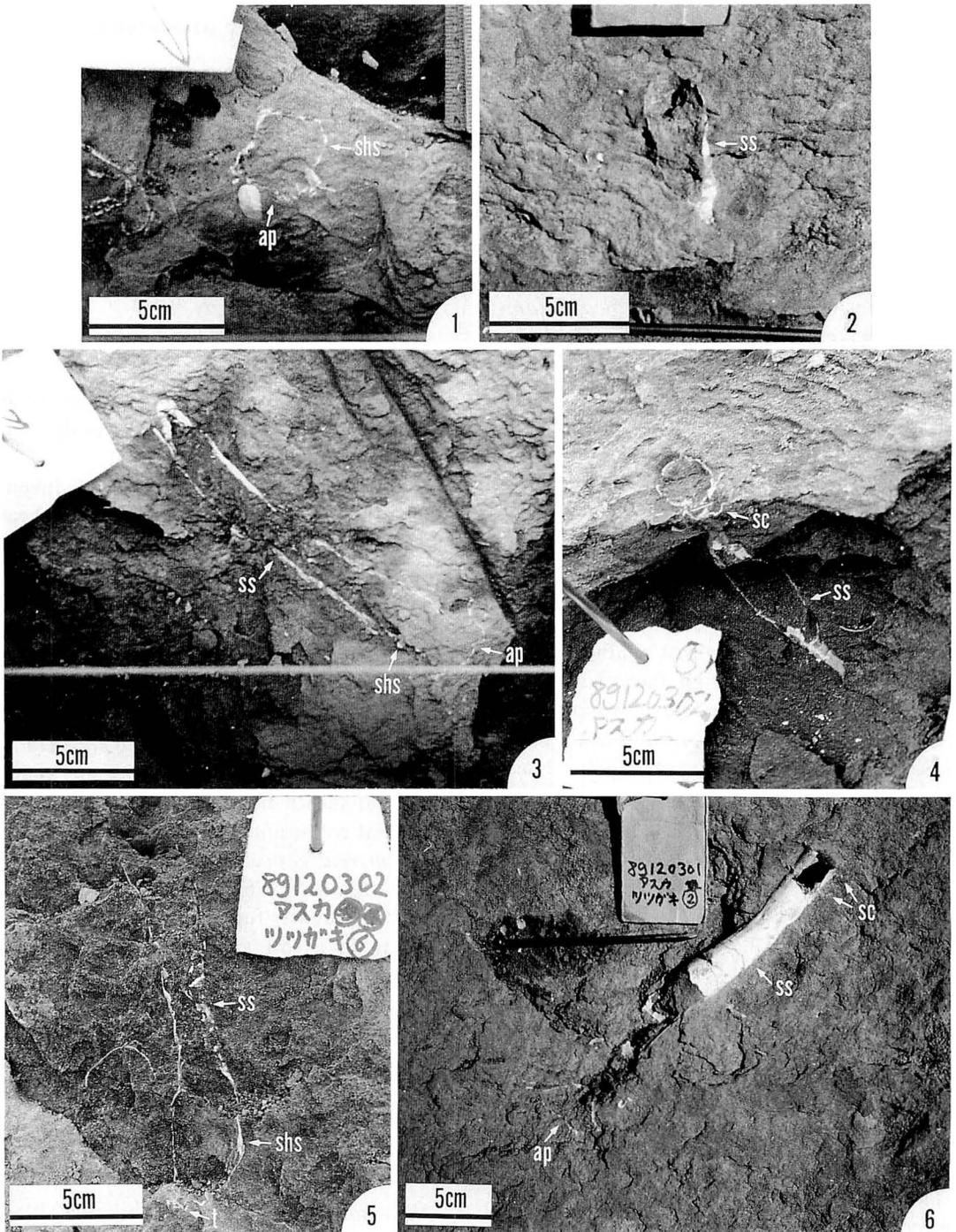
*Remarks.*—*Nipponoclava* has previously been considered to be a subgenus of *Humphyreia* Gray, 1858 (Smith, 1976; Pojeta and Sohl, 1987), but the latter has an angular siphonal sheath in transverse section and no siphonal collar and shows different life habit. *Humphyreia* is usually attached to hard substrata (Smith, 1976). Because the siphonal collar apparently functions to prevent further sinking in a soft substrate (Savazzi, 1982a, 1982b), the presence or absence of this character is important to establish their life habits.

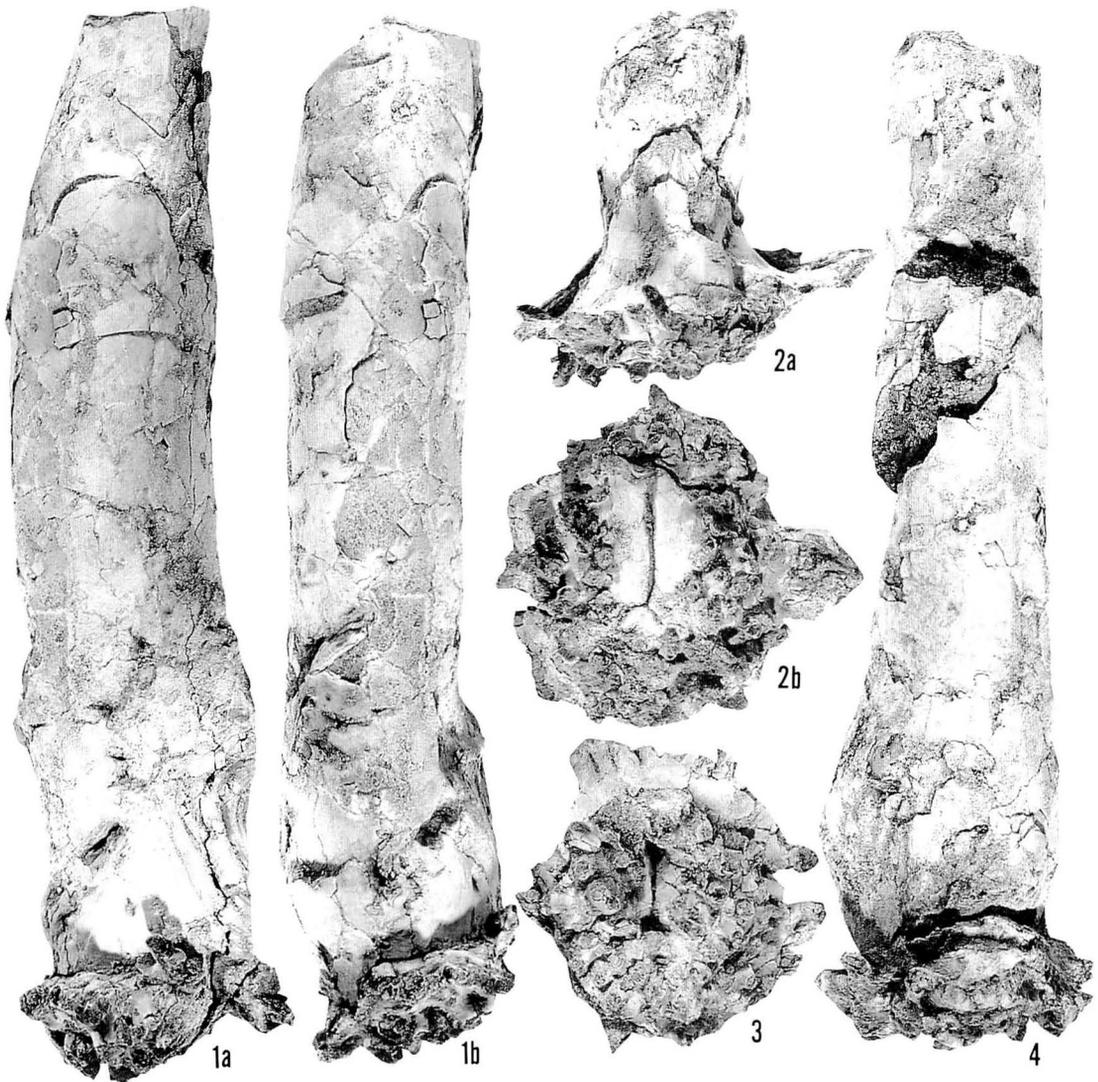
*Nipponoclava* is a genus endemic to Japan and consists of three species, *Nipponoclava gigantea* (Sowerby) (Holocene), *N. yokoyamai* (Shikama) (Pliocene-Pleistocene), and *N. kanazawaensis* (Omura) (Miocene).

*Nipponoclava yokoyamai* (Shikama, 1954)

Figures 3, 4, 5, 6.

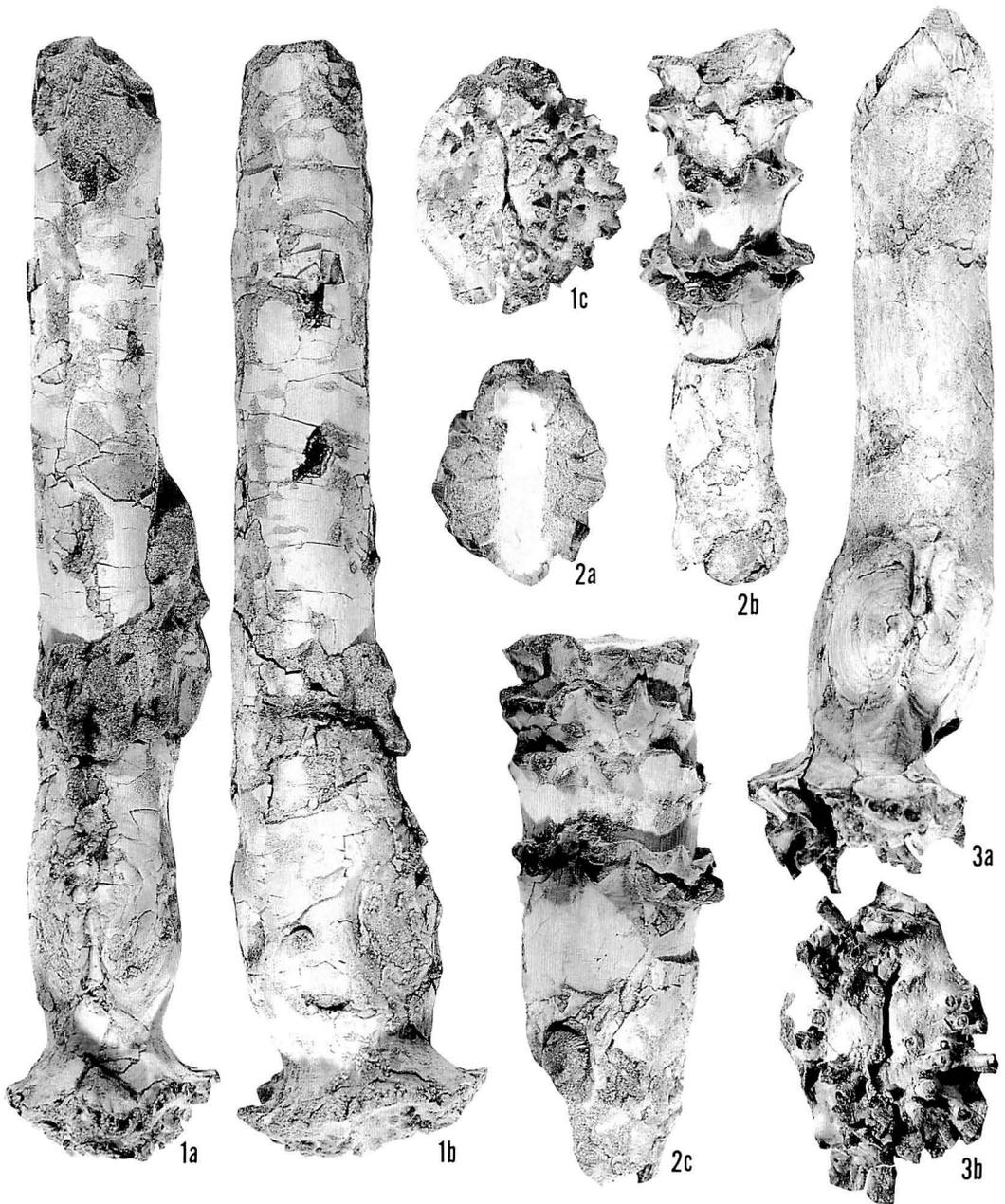
*Aspergillum giganteum* Pilsbry. Yokoyama, 1926a, p. 368, pl. 42, figs. 1, 2; Hatai and Nisiyama, 1952, p. 30 [*not Nipponoclava gigantea* (Sowerby,





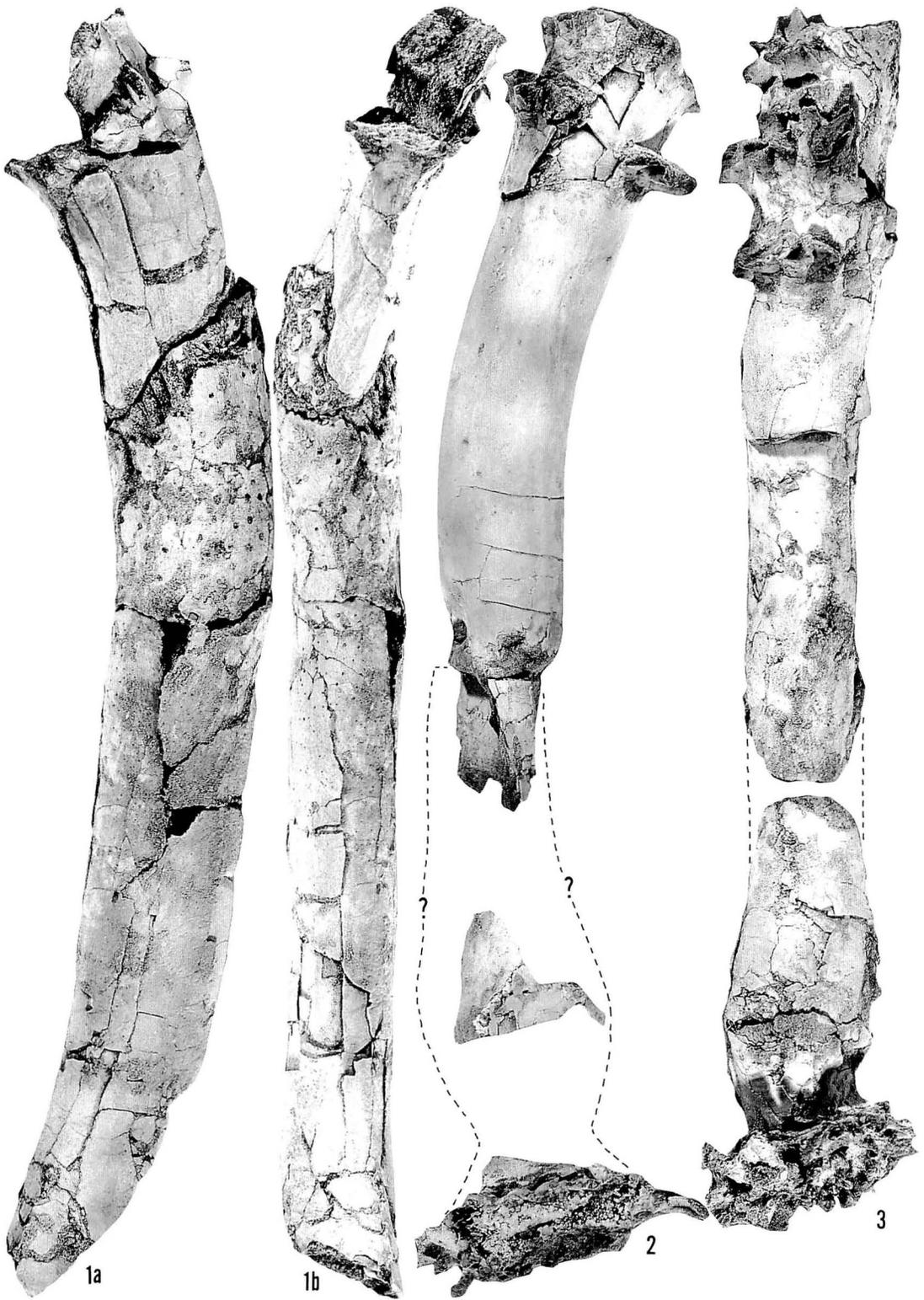
**Figure 4.** *Nipponoclava yokoyamai* (Shikama) from the upper Pliocene Ukari Formation, Shizuoka Prefecture. Natural size. **1a–b**, IGSU M033, IGSU loc. no. 52-56-8C, **1a**, right-lateral view, **1b**, ventral view; **2a–b**, IGSU M027, IGSU loc. 52-56-8A, **2a**, dorsal view, **2b**, anterior view; **3**, IGSU M021, IGSU loc. no. 52-56-8A, anterior view; and **4**, IGSU M035, IGSU loc. no. 52-56-8B, left-lateral view.

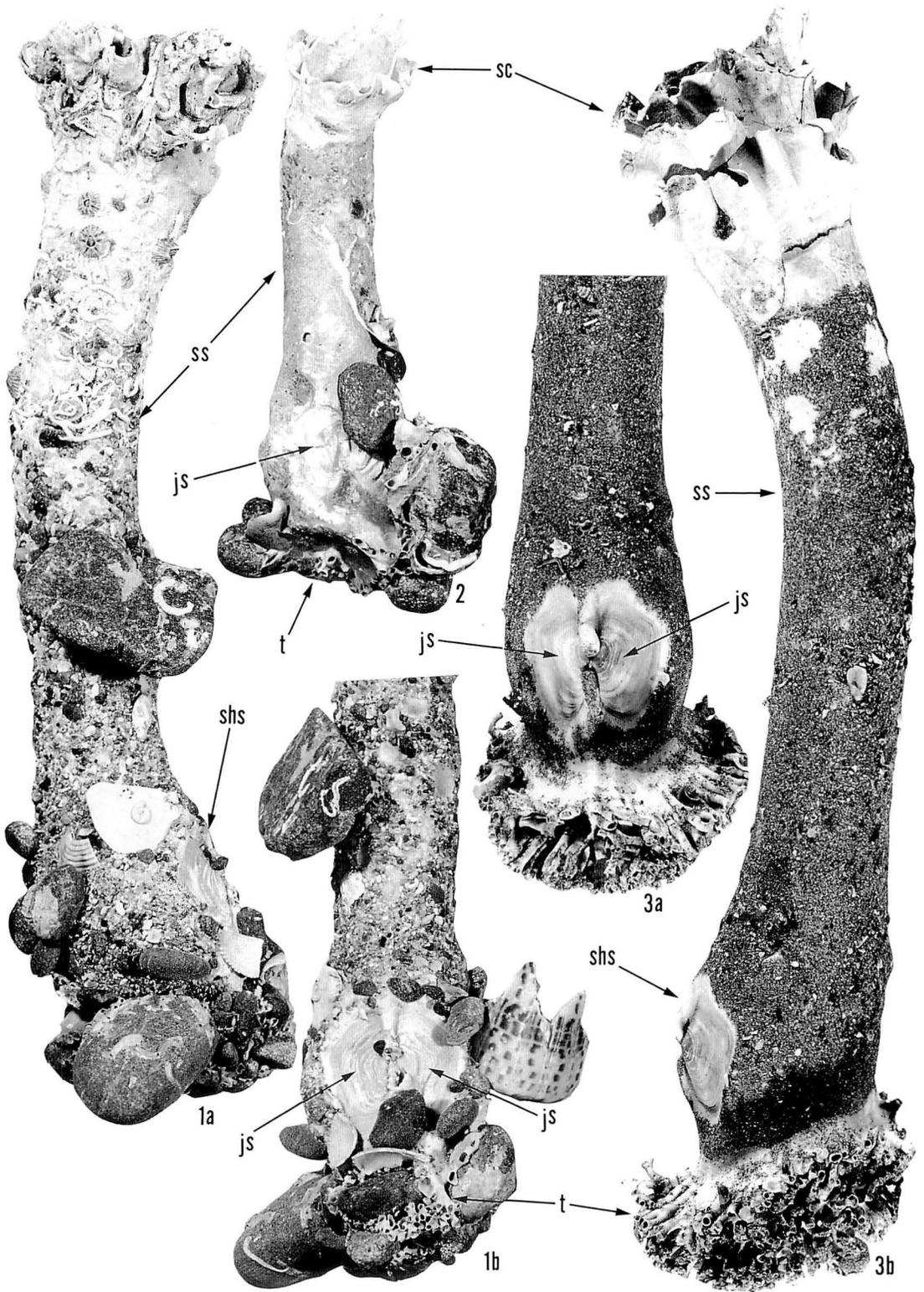
← **Figure 3.** Outcrop photos of *Nipponoclava yokoyamai* (Shikama) at IGSU loc. nos. 52-56-8A (**1, 3**), 52-56-8B (**2, 6**) and 52-56-8C (**4, 5**). **1**, lateral view, IGSU M023 (see **Figures 2-B-4, 4-3**); **2**, postero-lateral view, IGSU M029 (see **Figure 2-C-3**); **3**, lateral view, IGSU M026 (see **Figures 2-B-7, 2-C-2, 6-3**); **4**, postero-lateral view, missing during collection; **5**, lateral view, IGSU M033 (see **Figures 2-C-6, 4-1a–1b**); and **6**, lateral view, IGSU M030 (see **Figures 2-C-4, 6-2**). ap, anterior plate; sc, siphonal collars; shs, shell sheath; ss, siphonal sheath; t, tubules.



**Figure 5.** *Nipponoclava yokoyamai* (Shikama) from the upper Pliocene Ananai Formation. Natural size. **1a-c**, IGSU M017, IGSU loc. no. 61-54-4, **1a**, dorsal view, **1b**, right-lateral view, **1c**, anterior view; **2a-c**, IGSU M018, IGSU loc. no. 61-54-4, **2a**, anterior view, **2b**, ventral or dorsal view, **2c**, lateral view; and **3a-b**, IGSU M015, IGSU loc. no. 61-54-6, **3a**, dorsal view, **3b**, anterior view.

→ **Figure 6.** *Nipponoclava yokoyamai* (Shikama) from the lower Pleistocene part of the upper Pliocene to lower Pleistocene Takanabe Formation (**1a-b**) and from the upper Pliocene Ukari Formation (**2, 3**). **1a-b**,  $\times 0.78$ , IGSU M013, IGSU loc. no. 72-40-2, **1a**, left-lateral view, **1b**, dorsal view; **2**, IGSU M030,  $\times 0.85$ , IGSU loc. no. 52-56-8B, right-lateral view; and **3**,  $\times 0.85$ , IGSU M026, IGSU loc. no. 52-56-8A, left-lateral view.





1888)].

*Brechites* (*Warnea*) *yokoyamai* Shikama, 1954, p. 63-64, pl. 3, figs. 1a-d; Masuda and Noda, 1976, p. 44.

*Diagnosis.*—*Nipponoclava* with a strong contraction of crypt between shell sheath and anterior plate and with a distinct morph being greatly laterally depressed oval outline in cross section of sheath. Siphonal sheath has siphonal collars numbering less than five.

*Type material.*—UMUT CM23537 (Ichikawa, 1983: lectotype, herein designated), from northern slope of the hill near the boundary between Yasuda-machi and Tano-machi, about 600 m northeast of the shrine at Ono, Tano-machi, Aki-gun, Kochi Prefecture, Pacific side of southwestern Japan (Hatai and Nisiyama, 1952). Upper Pliocene Ananai Formation of Tonohama Group.

*Stratigraphic occurrence.*—Upper Pliocene and lower Pleistocene.

Upper Pliocene: Ukari Formation, Shizuoka Prefecture, IGSU loc. nos. 52-56-8A (Figure 3-1, 3-3, 4-2a-3, 6-3), 52-56-8B (Figures 3-2, 3-6, 4-4, 6-2), and 52-56-8C (Figures 3-4, 3-5, 4-1a-1b); Ananai Formation, Kochi Prefecture, IGSU loc. nos. 61-54-1, 61-54-4 (Figure 5-1a-2c), and 61-54-6 (Figure 5-3a-3b).

Lower Pleistocene: Takanabe Formation, Miyazaki Prefecture, IGSU loc. no. 72-40-2 (Figure 6-1a-1b).

*Remarks.*—*Nipponoclava yokoyamai* is characterized by having a strong contraction of the crypt between shell sheath and anterior plate and by having a morph showing a greatly laterally depressed oval outline in transverse sheath section. One specimen appears to show no contraction of the crypt (Figure 4-1a-1b), but the specimen lacks the hinge part of the juvenile shells and the shell sheath looks more slender than its true width. Probably, this specimen has a contraction of

the crypt. The transverse sheath section is largely variable in form from greatly laterally depressed oval (e.g., Figures 5-1a-2c, 6-1a-1b) to circular (e.g., Figure 6-2).

The siphonal sheath of one specimen is slightly but abruptly bent at the posterior part (Figure 6-1a-1b). This abrupt bend of the crypt is considered to be accidental and not a stable taxonomic feature of the species. The siphonal sheath of clavagellids is formed by periodic shell secretion at the posterior tips of the siphon, and the crypt further sinks with growth of the siphonal sheath into the sediments (Savazzi, 1982b; Pojeta and Sohl, 1987). The crypt orientation of this specimen might have been disturbed while growing and embedded into sediment. If the crypt was inclined by a disturbance, further burrowing would tend to realign the crypt vertically and result in an abruptly bending crypt (Savazzi, 1982b).

This species is very similar to *Nipponoclava gigantea* (Sowerby) (Figure 7), but the latter never has a sheath that is greatly laterally depressed oval in transverse section. Also, the latter never possesses a stronger contraction of the crypt between the shell sheath and the anterior plate than in *N. yokoyamai*. Figure 7-3a-3b illustrates one specimen of *N. gigantea* that most closely resembles *N. yokoyamai* among all the specimens of *N. gigantea* I have seen. This specimen has a contraction of the crypt, but it is not as distinct as in *N. yokoyamai*.

*Nipponoclava yokoyamai* and *N. gigantea* probably preferred different substrata. *Nipponoclava yokoyamai* had lived in silty sands since the autochthonous specimens occur always in silty sands. *Nipponoclava gigantea*, on the other hand, now lives in a gravel to sand bottom (Habe, 1977; Habe and Kosuge, 1970; Higo, 1973; Okutani and Habe, 1975; Okutani, ed., 1986). Although

← **Figure 7.** *Nipponoclava gigantea* (Sowerby) from off Nanbu-machi, Hidaka-gun, Wakayama Prefecture, on the Pacific side of southwestern Japan (Recent).  $\times 0.75$ . **1a-b**, IGSU M117, **1a**, right-lateral view, **1b**, dorsal view; **2**, IGSU M118, dorsal view; and **3a-b**, IGSU M012, **3a**, dorsal view, **3b**, left-lateral view. js, juvenile shell; sc, siphonal collars; shs, shell sheath; ss, siphonal sheath; t, tubules.

there is a possibility that these two species are different ecophenotypic forms within a single species living, respectively, in finer and coarser sediments, they could not justifiably be assigned to the case of ecophenotypy without finding evidence of an entirely continuous morphological link between the two.

*Nipponoclava kanazawaensis* (Omura), from a sandstone bed of the middle Miocene Sunakozaka Formation in central Japan, differs from the present species in having a small shell, attaining a maximum diameter of  $8.7 \times 11.6$  mm for the siphonal sheath, and a maximum diameter of  $9.0 \times 9.8$  mm for the shell sheath (Omura, 1969). The smallest specimen of *Nipponoclava yokoyamai* (IGSU M017: Figure 5-1a-1c) measures  $17.9 \times 19.1$  mm (siphonal sheath) and  $21.4 \times 19.1$  mm (shell sheath), respectively. The largest specimen (IGSU M013: Figure 6-1a-1b) has a diameter of  $22.5 \times 32.6$  mm at the posterior part of the siphonal sheath. Clavagellids predetermine the final adult size of the animal when the anterior part of the crypt including shell sheath and anterior plate is formed (Savazzi, 1982a, 1982b). The shell sheath and anterior plate show no growth line except for juvenile shells. The diameter of the crypt is, therefore, an important character to compare the size. Further comparison of these two species is difficult due to a poor state of preservation of *N. kanazawaensis*.

*Nipponoclava yokoyamai* has been known previously only from the three imperfect type specimens. It was originally reported by Yokoyama (1926a), under the name of *Aspergillum giganteum*, based on two shell-sheath fragments from the upper Pliocene Ananai Formation, Kochi Prefecture, on the Pacific side of southwestern Japan. Subsequently, Shikama (1954) proposed *Brechites* (*Warnea*) *yokoyamai* for Yokoyama's (1926a) specimens and one specimen in Dr. K. Sakurai's private collection which was collected from the Pliocene and lower Pleistocene Kakegawa Group, Shizuoka Prefecture, on the Pacific side of central Japan. The detail

of collecting locality of Sakurai's specimen is unknown and the specimen consists only of the anterior plate and shell sheath. This study is, therefore, the first detailed description of *N. yokoyamai*.

### Acknowledgments

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Aki 安芸, Ananai 穴内, Asuka 飛鳥, Ikenotani 池の谷, Kakegawa 掛川, Kawaminami 川南, Koyu 兎湯, Sunakozaka 砂子坂, Tano 田野, Tonohama 唐浜, Toriyama 通山, Ukari 宇刈, Yasudagawabashi 安田川橋.

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日本の鮮新—更新世暖流動物群から産する *Nipponoclava yokoyamai* (Shikama, 1954) (ハマユウガイ科: 二枚貝綱) の産出様式と再記載: 日本の太平洋岸に分布する上部鮮新統ないし下部更新統の宇刈層, 穴内層および高鍋層から採集された 25 個体の良く保存された標本にもとづいて *Nipponoclava yokoyamai* (Shikama) を再記載した。本種はこれまで 3 個の不完全標本しか知られていなかった。本種は *Nipponoclava gigantea* (Sowerby) と非常に良く似るが, shell sheath と anterior plate との間が強くくびれること, および sheath の断面において, つぶれた楕円形を呈する変異型が存在することで区別される。宇刈層の *N. yokoyamai* は, 暖流の上浅海帯を示す貝化石を散在的に含み, 強い生物擾乱を受けたシルト質砂岩から自生的に産出する。 間嶋隆一

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## 920. DISCOVERY OF A CORAL-RUDIST BUILDUP IN THE MIYAKO GROUP, NORTHEAST JAPAN

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**Abstract.** A coral-rudist limestone was newly discovered in the Lower Cretaceous (upper Aptian) sequence of the Miyako Group. It is small in scale but contains abundant frame-building organisms, notably autochthonous corals and rudists. Though vertical succession was not recognized, in some parts of the limestone, large and massive corals make a rigid framework, whereas in other parts the main frame-builder is *Praecaprotina yaegashii* (Yehara), a caprotinid rudist, which often forms clusters but does not show dense packing. This paper is the first concrete description of carbonate buildup in the Cretaceous of East Asia. Existence of coral-rudist buildup indicates that the northern limit of tropical-subtropical realm reached north Japan in late Aptian time. The influx of abundant clastic material may have prevented the buildup from the development of large-scale reefs, but small-scale buildups could grow, though temporarily or episodically, on the rocky shore in a transgressive stage.

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**Key words.** Carbonate buildup, Cretaceous, Miyako Group, Northeast Japan, paleoecology, rudist.

### Introduction

Rudist reefs have been known commonly in the platform carbonate rocks of the Caribbean, Middle East and Mediterranean regions as well as in the limestones on several sea mounts in the Pacific. Few examples of rudist-dominated reef deposits, however, were described in other regions, even if sporadic occurrences of rudist species have been known.

During my field survey, I discovered several buildups of hermatypic organisms along the base of the Early Cretaceous Miyako Group in north Honshu, Japan. One of these buildups is, though small in scale, clearly framed by corals and rudists. The purpose of this paper is to document the coexistence of *in situ* rudists and corals and to discuss its ecological

and biogeographic significance. The existence provides a rare and interesting example of Cretaceous carbonate buildup in the continental margin of East Asia.

### Geologic setting

The Miyako Group consists mainly of shallow high-energy open marine deposits that range from the upper Aptian to lower Albian (Hanai *et al.*, 1968). It abuts against various basement rocks of Jurassic and Early Cretaceous ages (andesite, granite, hemipelagic clastic rocks, *etc.*). Numerous well-preserved fossils (*e.g.*, bivalves, gastropods, ammonites, crinoids, *etc.*) were described from this group. Abundant hermatypic corals, nerineaceans, rudist and orbitolinid foraminifer, which indicate a warm environment, are noticed. Eguchi (1951) described 56 species belonging to 30 genera of corals, most of them are hermatypic ones. *Praeca-*

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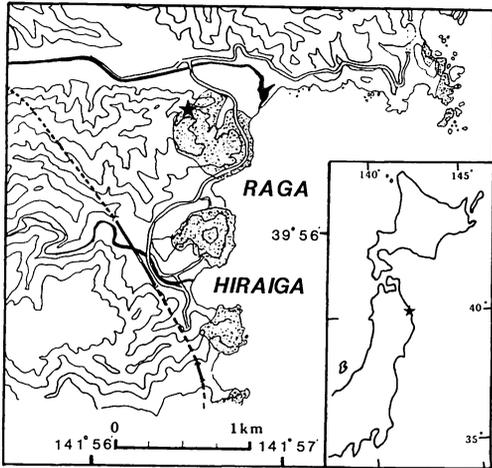


Figure 1. Map showing the locality of the coral-rudist limestone. Dotted area indicates the distribution of the Miyako Group.

*protina yaegashii* (Yehara), belonging to the family Caprotinidae, is the only described rudist species from this group (Yehara, 1920; Yabe and Nagao, 1926).

The coral-rudist limestone described here was discovered in the upper Aptian Tanohata Formation exposed on both banks of Kamakano-sawa stream, near Aketo, Tanohata-mura, Iwate Prefecture (Figure 1). This limestone lies on the andesite of the Neocomian Harachiyama Formation with clinounconformity.

Observation

The coral-rudist limestone is found on both banks of Kamakano-sawa stream (Figure 2). It crops out sporadically in a narrow area (about 20×50 m) and is mostly covered with

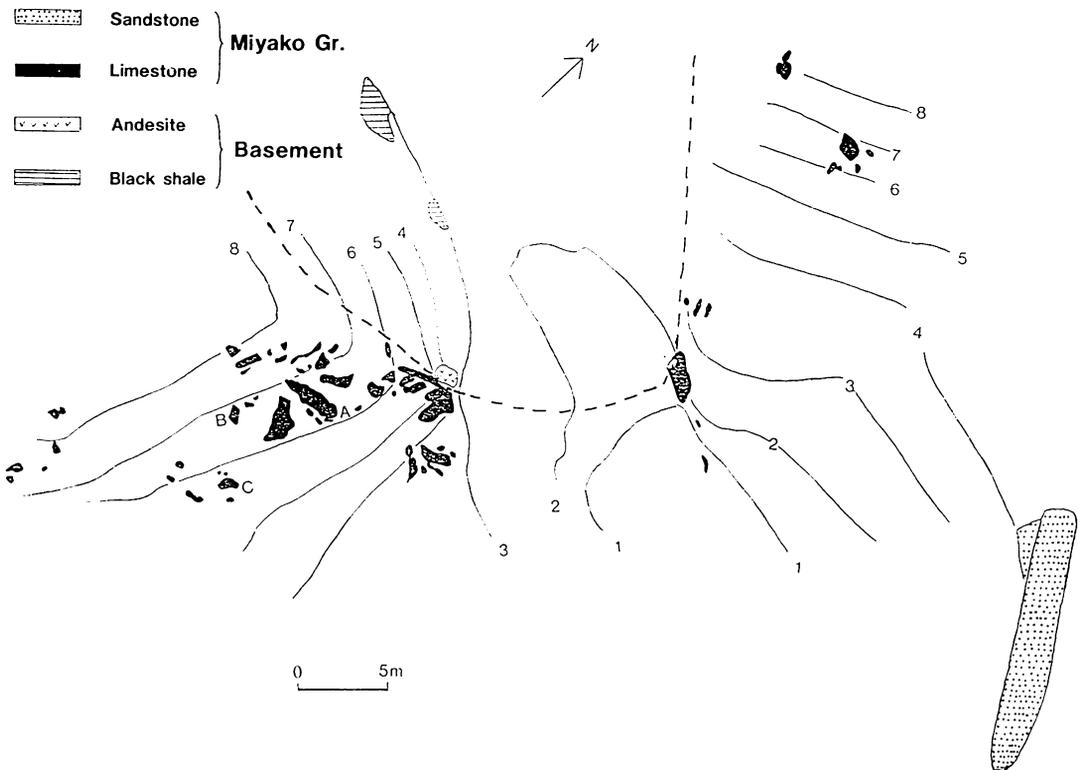


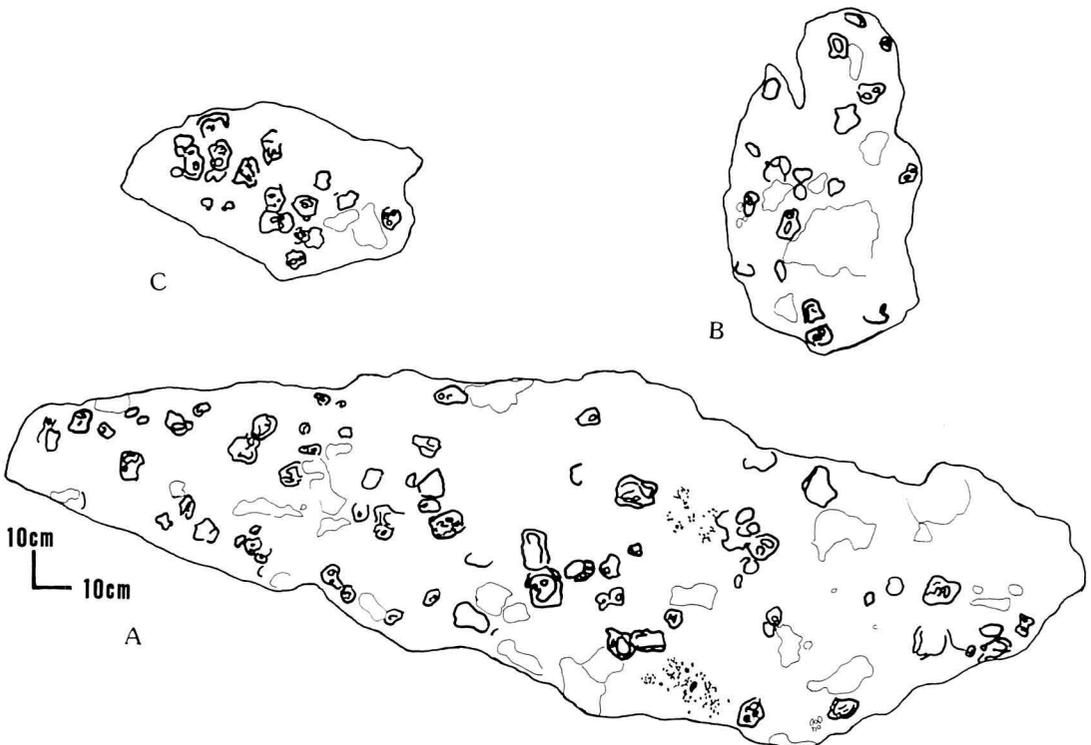
Figure 2. Map showing the outcrops of the coral-rudist limestone in Kamakano-sawa stream. Contour lines are drawn at intervals of about 1.5 m. Broken line indicates an approximate trace of unconformity.



**Figure 3.** Outcrop of the unconformity. The lower part is andesite, and the upper part is limestone. The hammer shown is about 33 cm long.

thick soil. On the south bank, the limestone is exposed on the southern slope of a small

ridge. Because the slope has nearly the same strike and dip with the Miyako Group of this area, the surface probably shows the weathered uppermost surface of the limestone. The unconformity can be observed at two localities, where the limestone directly covers the andesite (Figure 3). The thickness of this limestone is at least 1 m and may vary owing to the topographic relief of the basement. The limestone laterally merges into bioclast grainstone, particularly southwestward. In other directions the extension is unknown. The superjacent strata are not exposed there, but bioclast rudstone occurs at several meters above. The limestone is milky white and impure, containing numerous fragments of andesitic rock. It is tentatively divided into two parts by the difference of frame-builders.



**Figure 4.** Sketch of the upper surface of the coral-rudist limestone. A, B, C correspond to those in **Figure 2**. Distribution of macro-organisms are plotted. Bold line indicates rudist, slim line coral, and black spot unidentified dendroid organism. Note that most of rudist individuals are complete and oriented nearly perpendicularly to the surface. Some individuals of rudist are in contact with each other, forming clusters.



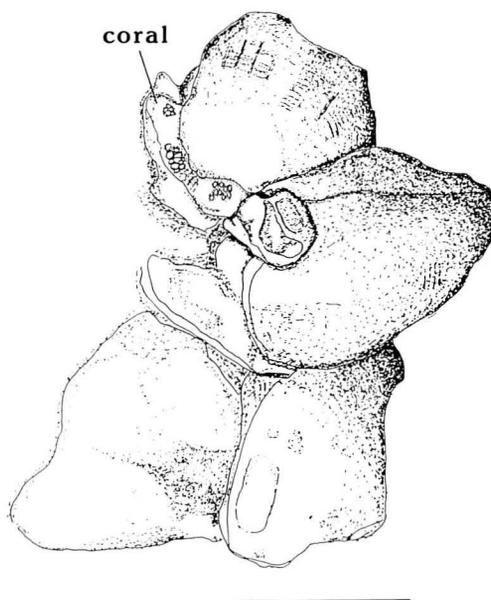
**Figure 5.** *Praeaprotina yaegashii* (Yehara). Transverse section on the limestone surface. Scale bar is 1 cm.



**Figure 6.** Distribution of rudist on an upper surface of the coral-rudist limestone. Several individuals are visible. The mechanical pencil is about 14 cm in length.

Some parts are dominated by corals, whereas in other parts the limestone contains numerous *in situ* individuals of rudist as well as corals. These two parts have patchy distribution in the limestone, and do not show any stratigraphic succession.

In the coral-dominated parts, the corals are generally of massive type. Their width is approximately 20–30 cm and attains about 50 cm at the maximum. Individuals of corals are not separately identified on the surface, but the growth direction examined in several specimens is always upward. A few rudist individuals (several cm in diameter) are associated in this part, but their systematic assignment is difficult due to the highly cemented matrix. The interior of the coral



**Figure 7.** Occurrence of several individuals of rudist and coral in the section of the upper part of the limestone. These organisms grew upward on top of other ones and are directly in contact with each other. Note that small individuals of rudist and coral encrust large rudist individuals, and that a rudist individual retains both the upper and lower valves. Scale bar is 5 cm.

skeleton is cemented by sparry calcite. Between the corals, fragments of *Lithothamnium* (?), small foraminifers, bivalves, echinoderms, quartz grains and a large amount of andesitic rock fragments are contained in the micritic matrix.

In other parts, individuals of organisms, mainly rudist, are easily discriminated from one another, but the limestone is massive and shows no conspicuous sedimentary structure. Figure 4 shows the distribution of rudist and corals on the bedding plane. Most individuals of the rudist and corals are not fragmented and often retain their original growth direction. Between individuals of the rudist and corals, well-preserved skeleton of an unidentified dendroid organism, and intact shells of brachiopods also occur. The rudist is positively identified with *Praeaprotina yaegashii* (Yehara) (Figure 5). Sometimes

both the upper and lower valves are found in original position. The rudist individuals are variable in size (3 cm–12 cm in diameter). They are crowded together and often in contact with one another, forming many clusters (Figure 6). Some individuals grew upward on top of other ones (Figure 7). The corals are mostly only several centimeters in width, and directly lie on rudist surface in some cases. At least several species of corals are discriminated in this part, though only *Eo-hydnophora* cf. *picteti* (Koby) and *Amphastrea yabei* Eguchi are identified to the species level.

Under a microscope, calcareous alga such as *Lithothamnium* (?) is seen to encrust on corals, and *vice versa*. The interspace of the frame-building organisms is filled by micritic matrix containing fragments of *Lithothamnium* (?), small foraminifers, corals and bivalves, as well as many grains of andesitic rocks and epigenetic pyrite.

### Discussion

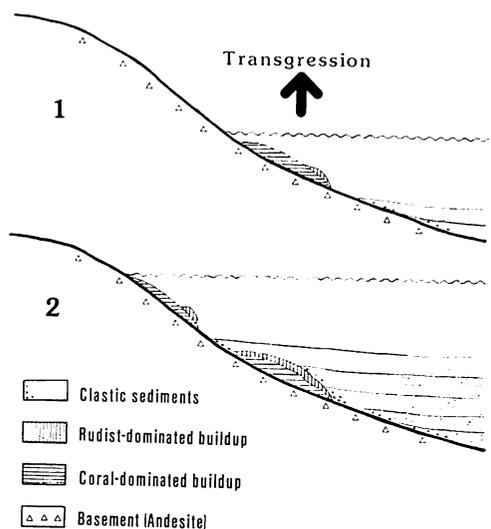
Many fossils of hermatypic organisms were recorded from the Miyako Group, but their descriptions were mostly based on allochthonous specimens which occurred in sandstone or conglomerate beds. There are few paleoecological studies. Therefore, the presence or absence of substantial reefs has been a controversial subject for a long time. Hanai *et al.* (1968) and Tanaka (1978) presumed the existence of barrier or patch reef. On the contrary, Mori (1984) assumed the absence of reef. He concluded that “corals by themselves did not form a rigid framework and were sporadically distributed on sand”.

The observed mode of occurrence of frame-building organisms (*e.g.*, their growth direction, direct pile and no fragmentation) indicates that this limestone abundantly contains autochthonous and coexisting corals and rudists. This is the first concrete description of carbonate buildup in the Miyako Group. These hermatypic organisms constructed the

rigid framework on the andesitic basement. The presence of beachrock was previously recorded by Hanai and Oji (1981) and encrusting bivalves and corals were reported from the beachrock, though it is very small in scale.

The limestone is impure and includes coarse-grained bioclasts and rock fragments between frame-builders. Among the frame-builders, corals are mostly massive in shape and piles up densely. Such a massive shape indicates a high-energy environment (James, 1983).

The newly discovered buildup is relatively small in scale (ca. 50×20×1 m), and other buildups observed in the basal part of the Miyako Group are even smaller in spite of abundant occurrence of hermatypic organisms. The probable scenario is as follows. Such a buildup was probably only locally formed in a transgressive stage. The influx



**Figure 8.** A model for the growth and shift of buildup in the Miyako Group. At the initial stage of transgression, a coral-dominated buildup grew on the basement. As the transgression proceeds, it was covered by a rudist-dominated buildup under a lower energy condition, and finally influx of abundant clastic material prevented further buildup growth. When favorable conditions came back, a new buildup started to grow at different places.

of abundant clastic material may have prevented the buildup from developing into large-scale reefs, and small-scale buildups could grow only temporarily or episodically on the rocky shore. The site favorable for the growth of frame-builders shifted obliquely upward along the slope during the transgression, and such a condition did not continue for long at any place (Figure 8).

The buildup of the Miyako Group represents an example considerably different from those of the platform carbonates in continental areas which are generally formed under a more stable and lower energy condition.

The sequential change of litho- and biofacies of the discovered limestone from the lower to the upper part may be meaningful. In the lower part corals are large and massive and make a rigid framework. In the upper part corals are small and they are no longer main constituents. The main frame-builder is the rudist, *Praeaprotina*, which sometimes forms clusters but does not show dense packing. Even a fragile skeleton of unidentified dendroid organism is preserved. Additionally, individuals of organisms are more easily identified, and the framework is less rigid than in the lower part. All these observations may suggest that the upper part was deposited in a relatively low-energy condition. Scott (1988) considered that corals, algae and stromatoporoids built the reef frame below normal wave base, and that caprotinids and other rudists composed a community in the high-energy wave zone. The result of my observation is somewhat different from his interpretation.

This is the first record of rudist-dominated buildup in East Asia. The upper part of this buildup probably corresponds to "coppice" in the classification of rudist frameworks by Kauffman and Sohl (1974). The rudist frameworks were scarcely developed in the North and South Temperate faunal realms (Kauffman 1973). Although Mori (1984) suggested that the Miyako Group was deposited under warm-temperate environments,

such as those in the present Pacific coasts from Kyushu to Honshu of Japan, the present discovery indicates that the northern limit of tropical-subtropical realm reached north Japan in late Aptian time. This interpretation agrees well with the occurrence of beachrock, and also many Tethyan-type molluscs from the Miyako Group.

### Acknowledgements

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Miyako 宮古, Tanohata 田野畑, Kamakano-sawa カマカノ沢, Aketo 明戸, Raga 羅賀, Hiraiga 平井賀, Harachiyama 原地山

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宮古層群におけるサンゴ-厚歯二枚貝ビルドアップの発見: 岩手県田野畑村明戸近傍の宮古層群基底部に, 自生の造礁性サンゴ類と厚歯二枚貝よりなる石灰岩を見いだした。この石灰岩は碎屑物を多く含む小規模なもの(50×20×1 m)である。ビルドアップは, 一部では主にサンゴが, 別な部分では主に厚歯二枚貝が枠組を造る。厚歯二枚貝のビルドアップは東アジア初の記録である。これは, 厚歯二枚貝類の礁状構造の分類によると“コピス”にあたり, アプチアン後期には熱帯-亜熱帯海域の北限が東北日本にまで及んでいたことを示す。多量の碎屑物の供給が大規模な礁の発達を妨げ, 小規模のビルドアップのみが, 海進期に一時的に, それも局所的に発達したと考えられる。このビルドアップは, 大陸地域の大規模なサンゴ礁や厚歯二枚貝礁とは非常に異なった例を提供している。佐野晋一

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**921. A NEW OCCURRENCE OF IMAGOTARIINE PINNIPED  
FROM THE MIDDLE MIOCENE GOUDO FORMATION  
IN HIGASHIMATSUYAMA CITY,  
SAITAMA, JAPAN\***

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**Abstract.** A pinniped tooth referable to the subfamily Imagotariinae Mitchell, 1968, is described from the earliest Middle Miocene Goudo Formation near Higashimatsuyama City, Saitama Prefecture. The tooth has an enlarged lingual cingulum, typical for the Late Miocene imagotariine *Imagotaria downsi* Mitchell, 1968, but an enlarged lingual cingulum with a large posterolingual protocone shelf on its crown seems also to be diagnostic for all the genera within that subfamily. Therefore, it has been identified herein only as a left upper second or third premolar of an indeterminate genus and species of the subfamily Imagotariinae. This record provides additional information about the paleobiogeographic and geochronologic distribution of imagotariine pinnipeds of the circum-North Pacific.

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**Key words.** Carnivora, Central Japan, Goudo Formation, Imagotariinae, Middle Miocene, Odobenidae.

### Introduction

The Miocene pinnipeds of the western North Pacific are still poorly known. Although a few materials have recently been reported (e.g., Dubrovo, 1981; Takeyama and Ozawa, 1984; Hirota *et al.*, 1987), almost all the other specimens have as yet to be described.

In the present paper, we describe a pinniped tooth referable to the subfamily Imagotariinae Mitchell, 1968, recovered from the earliest Middle Miocene Goudo Formation in the Iwadono Hills near Higashimat-

suyama City, Saitama Prefecture. The present record is the first mammalian fossil to be described from the Goudo Formation and is one of the oldest known imagotariine from the North Pacific realm. The specimen was collected by Mr. Takao Tahara on 23 September 1983, and has been stored at the Saitama Museum of Natural History (SMNH).

Preliminary work leading to this study was presented at the 137th Meeting of the Palaeontological Society of Japan (Kohno and Hasegawa, 1988).

### Systematic Description

In this paper, we adopted the classification

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of pinnipeds arranged by Barnes (1989) with a slight permutation on its family-group systematics in consideration of the recent controversy on its higher level taxonomy among all pinnipeds including the family Phocidae.

Order Carnivora  
Bowdich, 1821  
Family Odobenidae  
Allen, 1880  
Subfamily Imagotariinae  
Mitchell, 1968

Imagotariinae gen. et sp. indet.

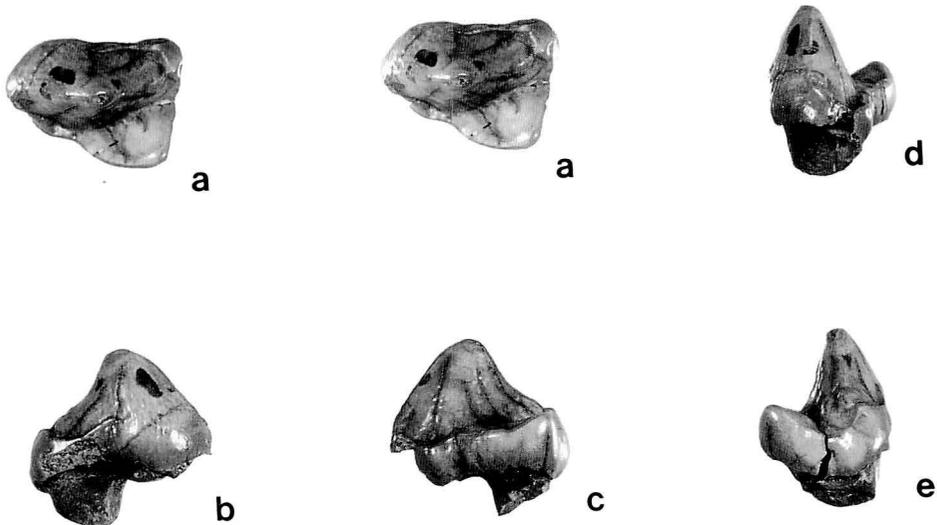
Figure 1a-e; Table 1

*Material*.—SMNH-V-e-37, left upper second or third premolar, lacking anterior and posterior roots at the base.

*Locality*.—A small valley at Negishi, located about 2.4 km southeast from the Musashi-Ranzan station of the Tobu-Tojyo Line, and about 3.9 km west of the Higashimatsuyama Interchange of the Kan-Etsu Expressway, Higashimatsuyama City, Saitama Prefecture, latitude 36°01'18" North, and longitude 139°20'38" East.

*Formation and Age*.—The specimen was found in a brownish, somewhat indurated, but partially weathered conglomerate in the basal part of the Goudo Formation (Majima, 1989), which is assignable to the lowest part of Blow's planktonic foraminiferal zone N. 9 (Matsumaru *et al.*, 1982) and is therefore the earliest Middle Miocene in age. Inuzuka (1985, table 2) listed, and Kohno and Hasegawa (1988) mentioned that a few desmostylian remains belonging to the genus *Palaeoparadoxia* have been found in the same formation at a different locality not far from Negishi.

*Description*.—The crown of the tooth is shaped like a scalene triangle in occlusal outline with a large posterolingual protocone shelf, that is completely separated from the paracone by a sharp groove. The paracone is situated near the midpoint of the buccal side as a principal cusp. It is broad and low, and a wear facet is on its occlusal tip. The metacone is reduced to a slight spur on the posterior side of the paracone. There is a small but distinct metastyle on the posterior end of the crown. The crown is surrounded by a continuous cingulum. The buccal cin-



**Figure 1.** Imagotariinae gen. et sp. indet., SMNH-V-e-37, left P<sup>2</sup> or P<sup>3</sup>. 2 times natural size. a, occlusal view (stereo photograph); b, buccal view; c, lingual view; d, anterior view; e, posterior view.

Table 1. Measurements of the specimen, SMNH-V-e-37, in millimeters

Mesiodistal diameter of the crown	12.8
Buccolingual diameter of the crown	10.2
Height of the crown at the buccal side	7.7
Mesiodistal diameter of the anterior root at the base	6.0
Buccolingual diameter of the anterior root at the base	5.1
Mesiodistal diameter of the posterior root at the base	3.8
Buccolingual diameter of the posterior root at the base	6.9

gulum is slightly inflated, but the lingual one is much enlarged. The lingual cingulum is divided into two parts, anterolingual and posterolingual, at a point slightly anterior to the middle of the crown by a shallow notch. The anterolingual cingulum forms a small cingular shelf. It expands posterolingually and is elevated into a prominent posterolingual "cusp". This tooth is distinctly two-rooted, although they are both broken off. The anterior root is round in cross section and the posterior one is elliptical at the base.

### Discussion

The structure and proportion of the crown, especially the well-developed lingual cingulum with the large posterolingual protocone shelf seen in the specimen SMNH-V-e-37 agree with the known upper cheek teeth of imagotariine pinnipeds, and consequently preclude an identification of the specimen as a non-imagotariine having no broad basin lingual to the metacone. Such characters as the relatively wide and low crown, the paracone bulging buccolingually, and a cingulum moderately expanding posterolingually, seem to indicate that the specimen is a left upper second or third premolar.

Five genera have been recognized so far within the subfamily Imagotariinae (Barnes, 1989). Among them, the monotypic genera *Pelagiartcos* Barnes, 1988 from the middle Middle Miocene and *Imagotaria* Mitchell, 1968 from the late Middle to early Late Miocene, both of California, have been

known with the large upper cheek teeth with enlarged, multiple cusped lingual cingulum on its crown. *Prototaria primigena* Takeyama and Ozawa, 1984, originally described as a primitive enaliarctine, from the early Middle Miocene of Fukui Prefecture, Japan was recently provisionally synonymized with the genus *Neotherium* and was transferred from the Enaliarctinae to the Imagotariinae by Barnes (1989). As can be seen from the illustration of Takeyama and Ozawa (1984), the skull of *Neotherium primigenum* (*sensu* Barnes, 1989: if the reassignment is correct) has a tooth, right upper third premolar, with enlarged, less cusped lingual cingulum like that of the specimen SMNH-V-e-37 and of the referred female specimen (Repenning and Tedford, 1977, pl. 6) of *Imagotaria downsi*. The monotypic genera *Kamtschatarctos* Dubrovo, 1981 from the Middle Miocene of Kamchatka and *Pontolis* True, 1905 from the latest Miocene of Oregon, were described on the basis of a partial cranium and a dentary without upper cheek teeth, and they cannot be compared directly with the specimen SMNH-V-e-37. *Pontolis magnus*, at least, is distinct from the specimen SMNH-V-e-37 on the basis of its considerably larger size. Furthermore, the two species are separated geochronologically by approximately 10 million years.

Among these species, the specimen resembles most closely the cheek teeth of *Neotherium primigenum* in their proportions, size, and cingular cusp arrangement. However, an enlarged lingual cingulum with a large

posterolingual protocone shelf seems to be diagnostic for all the genera within the Subfamily Imagotariinae and the development of cusps on the lingual cingulum and condition of root(s) also show a great variation. Therefore, it is impossible to determine whether this premolar pertains to the genus *Neotherium*, *Imagotaria* or even a new genus within the subfamily. Thus we identify it herein only as a left upper second or third premolar of an indeterminate genus and species of the Subfamily Imagotariinae.

Until recently, imagotariine pinnipeds have been known mainly from the middle Middle to latest Miocene of the eastern North Pacific (Repenning and Tedford, 1977). Therefore, the specimen SMNH-V-e-37 from the early Middle Miocene of Japan is one of the oldest known imagotariines, not only in the western Pacific but also anywhere in the North Pacific. In addition, the tooth morphology of the specimen as mentioned above is considerably primitive for the subfamily. Thus the specimen probably belongs to the most primitive imagotariine that evolved from a certain species within the enaliarctine pinnipeds in Early Miocene time.

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埼玉県東松山市付近に分布する中部中新統神戸層下部の礫岩層より、イマゴタリア亜科に属する鱈脚類の臼歯化石が発見された。当該標本は歯冠高が低く、歯冠の遠位舌側に極めて発達のない歯帯を持つことなどから、セイウチ科のイマゴタリア亜科に属する鱈脚類の、左上顎第2もしくは第3前臼歯と判断される。北太平洋沿岸域におけるこの仲間の記録としては、これまでに知られる限り最も古いものの一つとなる。当該標本は、単離した1個の臼歯であるため属種を決定できないが、プロトコーンシェルフがよく発達していることや、2歯根であるなど原始的特徴を保持しており、ほぼ同時代から知られているセイウチ類の祖先とされる、ネオテリウム類の臼歯に最もよく類似している。このことから、当該標本は最古の鱈脚類であるエナリアルクトス類から、セイウチの系統に分かれた初期の仲間のひとつであったろうと思われる。

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甲能直樹・長谷川善和

SHORT NOTES

**26. *SIPHONOBASIS*, REPLACEMENT NAME FOR *CASSIOPELLA*  
KASE, 1984 (MOLLUSCA : GASTROPODA), NON WHITE, 1877\***

TOMOKI KASE

Department of Geology, National Science Museum, Tokyo 169

Kase (1984) proposed a new subgenus *Cassiopella* for *Cassiope* [type species *Cassiope (Cassiopella) ogaii* Kase, 1984]. However, the recent publication of a monograph of the Cassiopidae by Cleevly and Morris (1988) has brought my attention to the fact that the name is preoccupied by a genus of a gastropod from North America (White, 1877, p. 606). As the name *Cassiopella* becomes unavailable, it is proposed that it be replaced by a new name *Siphonobasis*. The generic name is compound from *siphono*, Greek, meaning "siphon or tube", and *basis*, Greek,

meaning "base or bottom," in reference to the siphonate base of the shell.

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- ◎1992年年会・総会は、1992年1月25日、26日、27日に九州大学理学部で開催されます。講演申込は12月10日（必着）締切です。講演申込の方法が変更になっています。詳しくは「化石」48号をご覧ください。
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